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Tomato Cleaning and Water Recycle

National Food Processors Association
Berkeley, CA

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A full-scale dump tank water recycle system was developed and demonstrated. A false bottom-ejector transport system removed soil from the water. Clarified water was either recycled back to the dump tank or discharged to the sewer. A vacuum belt was developed for dewatering the mud prior to final disposal.

Two types of rubber disc machines were evaluated for the cleaning of tomatoes. Both were found to be effective in cleaning the tomato surfaces using minimal amounts of water. Cleaning was accomplished by the rubbing action of soft rotating rubber discs. Substantial amounts of stems were removed from the tomatoes by the rubber disc machines.

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TOMATO CLEANING AND WATER RECYCLE

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report presents an evaluation of a full scale dump tank water recycle system and a low water-mechanical product cleaner. A physical/chemical system was used to remove mud from water which was then either recycled back to a dump tank or discharged to a sewer. Tomatoes were cleaned by a combination of low water and rotating rubber discs. Fewer pollutants were discharged and more product was processed by this system as compared to the conventional system. Further information on the subject can be obtained by contacting the Food and Wood Products Branch, Industrial Environmental Research Laboratory-Cincinnati.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

This project was undertaken to develop a mud removal-water recycle system for a tomato dump tank operation and to demonstrate that mechanical energy in the form of soft rotating rubber discs could effectively clean tomatoes.

Over the 1974, 1975 and 1976 operating seasons, modifications and improvements were made to the mud removal-water recycle system. A false bottom-ejector transport system was developed to prevent soil from settling in the dump tank. A physical/chemical treatment system was developed to remove soil from water being recycled back into the dump tank. Colloidal particles were removed from the thickener overflow tank before either being recycled back to the dump tank or discharged to the sewer. A vacuum belt dewatering unit was constructed and evaluated for dewatering mud from the thickener tank prior to final disposal.

Two different designs of rubber disc machines were evaluated and found to be equally effective in cleaning the surface of tomatoes. Minimal quantities of water were required in the cleaning of the tomatoes. Energy in the form of the soft spinning rubber discs removed the surface soil from the tomatoes. It was also observed that stems were removed from the tomatoes by the disc cleaners.

This report was submitted in fulfillment of Grant No. S-803251 by the National Canners Association, now the National Food Processors Association, under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers a data collection period from July 1, 1974 to March 31, 1977.

Note: This report follows the prevailing canning industry practice of using the international system of units in the laboratory and U.S. units in the manufacturing operations. A table of conversion factors is included.

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METRIC CONVERSION

To Convert from	To	Multiply by
inch (in)	meter (m)	2.5×10^{-2}
foot (ft)	meter (m)	3.048×10^{-1}
gallon (gal)	meter^3 (m^3)	3.785×10^{-3}
pound (lb)	kilogram (kg)	4.536×10^{-1}
ounce (oz)	kilogram (kg)	3.11×10^{-2}
gallon per ton (gal/ton)	meter^3/kilokilogram (m^3/kkg)	4.17×10^{3}
pounds per ton (lb/ton)	kilogram/kilokilogram (k/kkg)	4.643×10^{-1}
tons per hour (ton/hr)	kilokilogram/hr (kkg/hr)	9.074×10^{-1}
gallons per minute (gpm)	meters^3/min (m^3/min)	3.785×10^{-3}
foot per second (ft/sec)	meters/sec (m/sec)	0.305
cubic feet per second (cfs)	liters/sec (l/s)	28.316
cubic yard (yd^3)	meters3 (m^3)	0.765

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SECTION 1

INTRODUCTION

Mechanical harvesting of raw products has increased the amounts of soil being transported, with the product, to the food processing plant. The quantity of soil varies from one to five percent of the weight of the product. For tomatoes, the weight of soil is two percent or more (1,2). The soil is characterized in two forms: 1) as clods of dirt and 2) as smear soil on the surface of the product. This increase in soil concentration has caused food processors to use more water to clean the product.

Soil solids accumulate in the bottom of dump tanks or initial flumes when the velocity of water in these systems is insufficient to scour the bottom surface of the tank. After several hours of dumping, the soil accumulates to the extent that product flow is impaired and process time down is required for the physical removal of the soil.

Until recently, the industry either used high water scouring velocities to prevent soil from settling or allowed it to settle. Periodically the plant stopped processing to remove the accumulated soil. Due to disadvantages of these practices a need existed to improve methods for handling the soil problem. The use of high water flow rates results in the discharge of excessive amounts of water which adds to the hydraulic portion of surcharges. The discharge of inert solids (soil) to a municipal waste treatment system can result in operational and maintenance problems. The intermittant shut down by the processing plant not only reduces the plant's productivity, but also requires additional water for clean up purposes.

The study described in this report was initiated to seek solutions to problems related to the processing of machine harvested tomatoes. The specific objectives of the project were:

1. To demonstrate on a commercial scale the substantial reduction in the volume of water required to clean tomatoes by using a flexible, spinning rubber disc machine.
2. To develop a water recycle system for tomato dump tank water.

3. To compare the cleanliness (based on bacteriological and physical criteria) of tomatoes processed in a conventional washing system with a low water cleaning/washing system.

4. To compare the plant effluent, with regard to volume, BOD and suspended solids, between the conventional and low water cleaning systems.

5. To make economic comparisons between: a) conventional washing system VS disc cleaner, b) conventional washing system with dump tank recycle (no chemical flocculation) VS disc cleaner with dump tank recycle (no chemical flocculation), c) disc cleaner without dump tank recycle VS disc cleaner with dump tank recycle (no chemical flocculation), and d) disc cleaner with dump tank recycle (with chemical flocculation) VS disc cleaner with dump tank recycle (no chemical flocculation.)

The project encompassed the 1974, 1975 and 1976 processing seasons. On March 15, 1974 a proposal was submitted to the U.S. Environmental Protection Agency by the Research Foundation, National Food Processors Association. EUTEK Process Development and Engineering was selected as a subcontractor to the project and was responsible for the design and construction of the water recycle system. The National Food Processors Association was responsible for the operation of the water recycle system and for the collection and analysis of samples.

SECTION 2

CONCLUSIONS

The wastewater management objective for a tomato processor is to implement systems which minimize wastewater related costs. Using parameter values found in this report, it was demonstrated that installations and operation of an in-plant water recycle system with off-line mud removal could save approximately 50% of the total annual wastewater related costs. For the 30 ton/hr plant evaluated, annual savings could amount to approximately $47,000.

Performance parameter values were obtained from investigating four modes of operation; conventional cleaning, conventional cleaning with water recycle, disc cleaner with water recycle, and disc cleaner with recycle and chemical coagulation-flocculation.

The daily average tonnage of tomatoes processed increased substantially with disc cleaning and water recycle as compared to the conventional system. The observed increase of 26% in the tonnage of tomatoes processed may be primarily due to the virtual elimination of solids accumulation in the dump tank. No incident of temporary shutdown of shift operation for the purpose of removing soil from the dump tank was encountered during the modes of operation with water recycle.

The following findings were established in this study:

1. The majority of daily water usage was for operational purposes (48-61%), followed by clean-up (31-44%) and filling (6-8%) purposes. Regardless of the mode of operation, no significant variation in the percentage of total daily water used was observed.

2. A decrease of 25% in the average total daily water usage was realized with a disc cleaner and water recycling with chemical flocculation.

3. The daily average tonnage of tomatoes processed increased substantially during modes of operation with water recycling.

For instance, an increase of 25% in the tonnage of tomatoes was realized when the disc cleaner with water recycle and chemical flocculation was used. These increases in the daily tonnage of tomatoes processed may be primarily due to the improved soil solids removal efficiency. No incidence of temporary shutdown of the operation was encountered during the modes of operation employing water recycling.

4. A significant finding was a substantial decrease in the average unit water consumption rate (gallons of water per ton of tomatoes processed) when water recycling measures were applied. A 41% decrease in average unit water consumption rate was realized when disc cleaner with water recycling and chemical flocculation was applied.

5. When water conservation and reuse measures were implemented, the soils solids removed from the dump tank per ton of tomatoes processed decreased, soil solids lost to sewer decreased and the soil solids removed from the thickener tank per ton of tomatoes processed increased.

6. The estimated soil solids incoming to the plant per unit weight of tomatoes processed ranged from 10 to 20 lbs/ton, having an average of 13 lbs soil solids per ton of tomatoes processed. The total soil solids from raw tomatoes were estimated from the sum of soil solids which were collected from the dump tank, lost to the sewer, and removed from the sludge thickener. It appears that the amount of soil solids to the plant varied considerably and depended upon the type of soil from which the tomatoes were grown, the moisture content of the soil when the tomatoes were harvested, and the method of tomato harvesting.

7. In addition to the savings associated with wastewater, the increase in tonage of tomatoes represents a potential annual labor savings of $54,000.

SECTION 3

RECOMMENDATIONS

A method for the removal of soil from water and the recycle of water in a dump tank operation has been demonstrated and should be placed into commercial use. A method to clean tomatoes using a low volume of water has been demonstrated and should be placed into commercial use.

Vines, stems, grass and other materials accumulate at product transfer points and there is a need to find effective methods of removing these materials. On occasion the spacings in the false bottom become clogged with soil clods, rocks, metal trash, etc. and there is a need to devise a method to periodically clean the false bottom spacings.

SECTION 4

EXPERIMENTAL DESIGN AND PROCEDURE

DUMP TANK WATER RECYCLE

The initial approach used in the development of a water recycle system was to maintain a high water velocity in the dump tank and to withdraw, treat and return water. The withdrawn water was treated then returned to the dump tank at various locations. It was postulated that water would be of sufficient volume and have sufficient head to maintain a scouring effect along the entire bottom of the dump tank.

The design work officially began with project authorization in mid-June of 1974. Fabrication of the solids removal unit was completed by the end of August. Testing of the system was initiated during the first week of October.

Figure 1 is a flow diagram of the water recycle system for the 30 ton/hr. tomato bin dump. The system operated either with or without flocculation. Operating without flocculation, the primary pump transfered water from the base of the elevator to the swirl concentrator. Concentrated settleable solids continuously discharged from the swirl concentrator to the thickener located below. The underflow from the swirl concentrator was orifice restricted to a constant flow of 50 gpm. The balance of the recycled water overflowed from the swirl concentrator and discharged through return scouring jets located in the base of the bin dump. The clarified underflow stream overflowed from the thickener and returned to the bin dump. An additional scouring jet header operated directly off the primary pump discharge line. This additional flow was required to obtain design flows through the scouring jets.

Supply water for the flocculation system was taken from the swirl concentrator overflow water returning to the scouring jets. Coagulant added to this flow resulted in a flocculated admixture from the flocculator/concentrator. The clear water overflow returned directly to the bin dump while the underflow returned to the thickener for gravity clarification.

Due to delays in authorization of the project, and difficulties encountered in start-up of the new water recycle system in the midst of the tomato

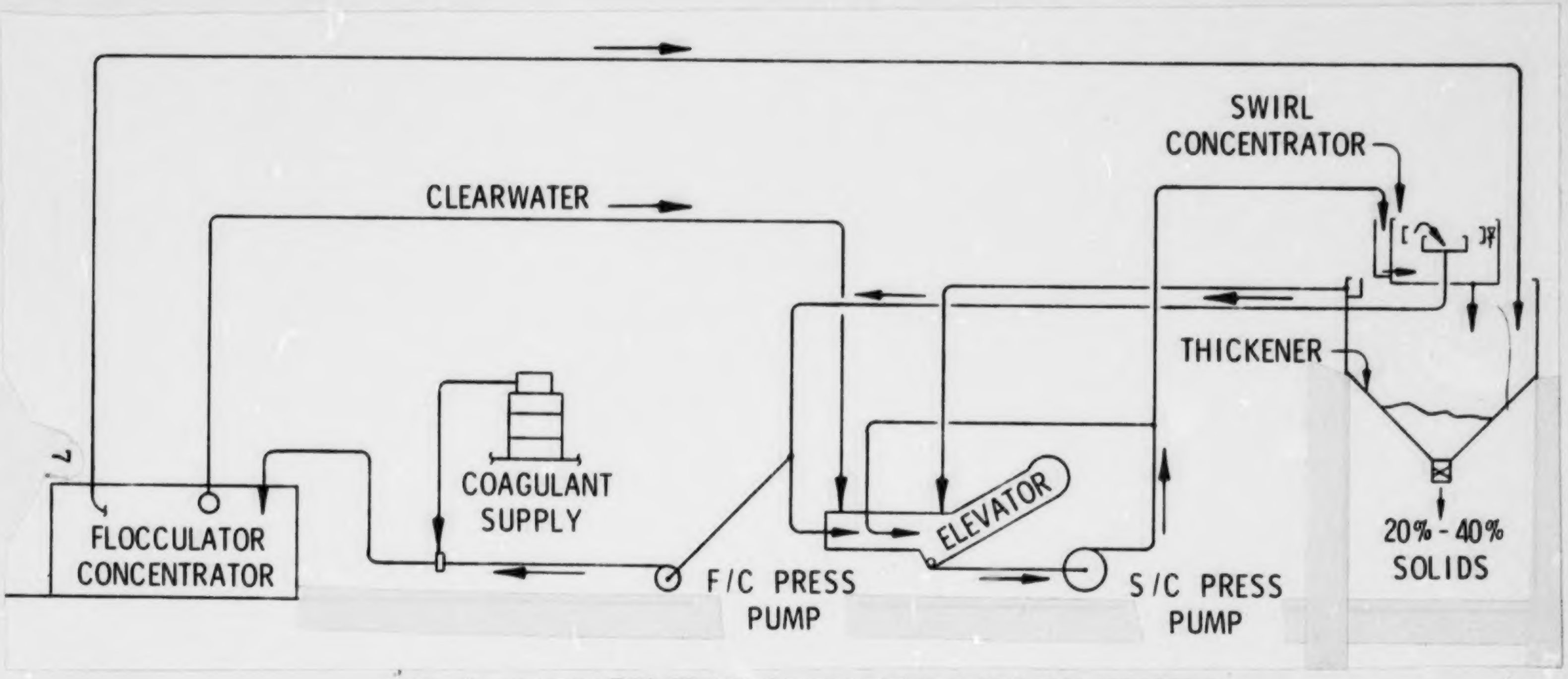

SWIRL CONCENTRATOR
CLEARWATER
THICKENER
COAGULANT SUPPLY
ELEVATOR
FLOCCULATOR CONCENTRATOR
F/C PRESS PUMP
S/C PRESS PUMP
20% - 40% SOLIDS

FIG. 1 FLOW DIAGRAM OF WATER RECYCLE SYSTEM

processing season, only a few weeks of meaningful runs were obtained. The 1974 project began during the first half of the month of September and the tomato processing season was terminated during the first week of October.

The primary objective of the 1974 test program was to determine if it was feasible to maintain a closed loop system of water usage around the tomato bin dump. A second objective was to evaluate a technique of utilizing high scouring velocities at the base of the bin dump to prevent accumulations of settleable solids within the bin dump itself. The third and final objective of the study was to determine what benefits, if any, would accrue from the use of a coagulation and flocculation system used in conjunction with the closed loop water recycle system.

The key findings of the 1974 water recycle project (3) were:

1. Insufficient Data Coverage. The hastily assembled flow monitoring and sampling system failed to provide sufficient data to accurately determine hydraulic and mass balances. While some conclusions were drawn, they were limited due to the very small amount of data upon which they were based.

2. Unsatisfactory Mud Removal Procedure. The scouring jets, when operating, efficiently prevented the accumulation of settleable solids on the base of the bin dump, however, the high velocities required for accomplishing this resulted in the loss of the "hydraulic cushion" which is the single most important feature of the bin dump operation. Bin dumps are employed to accomplish a product flow conversion from the erratic surges due to the staggered bin dumps to a smooth product flow from the bin dump product elevator. As a consequence of the high scouring velocities in the base of the bin dump tank, this hydraulic cushion was eliminated and the unloaded bins of product were almost instantaneously transferred in mass to the product elevator causing surging in the subsequent fluming operations.

3. Clogging of Recycle System Mechanical Elements. Due to project schedule limitations, it was not possible to incorporate a long delivery gravity screen into the closed loop. As a consequence the floatable materials (vines, leaves and grass) accumulated within the system and eventually resulted in the clogging of pump and propellers, turbine water meters, and other key mechanical elements as well as the return scouring jets to the bin dump.

4. Lack of Soil Solids Concentration. The swirl concentrator effectively separated the soil as an under-flow to the thickener tank. However, removal of solids from the tank was not adequate. Bridging of soil within the tank prevented withdrawal of soil in high concentration.

5. Lack of Liquid Level Control in the Bin Dump. The water recycle system was not coupled or controlled by the liquid level in the bin dump. Overflow from the system occurred from the bin dump. As a result, at times make-up water entering the bin dump from downstream flumes and return water from the water recycle systems caused the bin dump to overflow. This resulted in a loss of product and bin dump water.

6. No Automatic Control of Coagulant Dosage. The flocculation system utilized a manually adjusted coagulant feed which made it difficult to achieve and maintain a regulated coagulant dosage when the flocculation system was operated. Correction of this was believed to require some type of automatic turbidimetric sensing system which would proportion coagulant dosage to the received signal.

Major modifications were required in subsequent operation of the recycle system to assure its ability to meet the general project objectives.

Four general objectives were set for the 1975 season:

1. Modify and improve on the water recycle system for the tomato dump tank water.

2. Compare wastewater quantity and quality under different operating modes.

3. Compare the quality of final discharged waters from the system with and without the addition of coagulation/flocculation.

4. Economically compare the consequences of operation of the initial bin dump with and without the water recycle system and with the water recycle system operating in different modes.

MODEL DUMP TANK STUDY

In January of 1975, a proposal was submitted to carry out a bin dump tank model study. The proposed grit collection system consisted of a false bottom near the point where tomatoes were dumped into water. Grit would pass through the false bottom and be transported, by means of an ejector, to a solids separation system.

Model Design Criteria

The flow conditions within the bin dump tank under normal operating conditions were turbulent with gravitational forces governing the settlement of the grit solids in the base of the tank. Under these conditions, the Froude Number applied.

$$N_F = \frac{U}{gL} \qquad (1)$$

where,

U = velocity (fps)

g = gravitational acceleration (32.2 ft/sec^2)

L = dimension (ft)

Equation 1 provided the basis for relating model to full scale dimensions and flow characteristics. The relationship of the model flows to full scale flow was obtained by combining the scale and velocity factors from Equation 1 as follows:

$$Q = UL^2 \qquad (2)$$

$= N_F$ = Froude Number

Q = flow rate (CFS)

g = gravitational acceleration (32.2 ft/sec^2)

L = dimension (ft)

Table 1 lists the design parameters and their magnitude fot the full scale bin dump. Also listed on the table are the magnitudes of a half-scale model system which maintains Froude Number similarity. All listed parameters are defined in Figure 2.

Figure 3 shows the alternative methods for introducing recirculated water into the bin dump. The two configurations, jet flow and weir overflow, differ in that the jet flow system sustains high velocities for greater distances through the bin dump tank than does the weir overflow method. These two methods of water introduction were evaluated to determine if soil deposition could be concentrated near the point of introduction.

TABLE 1

MODEL BIN DUMP DESIGN PARAMETETERS

Symbol	Description	Units	Full Scale Magnitude	Model Magnitude
Dimensions				
L	Bin Dump Length	ft.	15.0	7.5
W	Bin Dump Width	ft.	4.0	2.0
H_W	Bin Dump Water Depth	ft.	1.0	0.5
H	Bin Dump Water Height Above G. L.	ft.	2.5	3.0
H_D	Dumper Axis Height Above Bottom	ft.	4.0	2.1
L_D	Dumper Axis From End	ft.	3.5	1.75
H_H	Hopper Depth	ft.	2.0	1.0
L_H	False Bottom Hopper Length	ft.	4.0	2.0
H_T	Ejector & Below Bottom	ft.	1.75	1.0
H_R	Height of Recirculated Flow Return	in.	3.0	1.5
H_E	Ejector Hydraulic Head	ft.	10.5	5.25
D_T	Soil Transport Line Diameter	in.	6.0	3.0
D_S	Scour Line Diameter	in.	4.0	2.0
Flows				
Q_R	Recirculated Flow to Bin Dump	gpm	300	53
Q_E	Ejector Motive Flow	gpm	250	44
Q_S	Scour Flow	gpm	<250	44
Q_T	Soil Transport Flow	gpm	500	88
Q_P	Product Transport Flow	gpm	300	53
Velocities				
U_R	Recirculated Flow Jet Velocity	fps	9.2	6.5

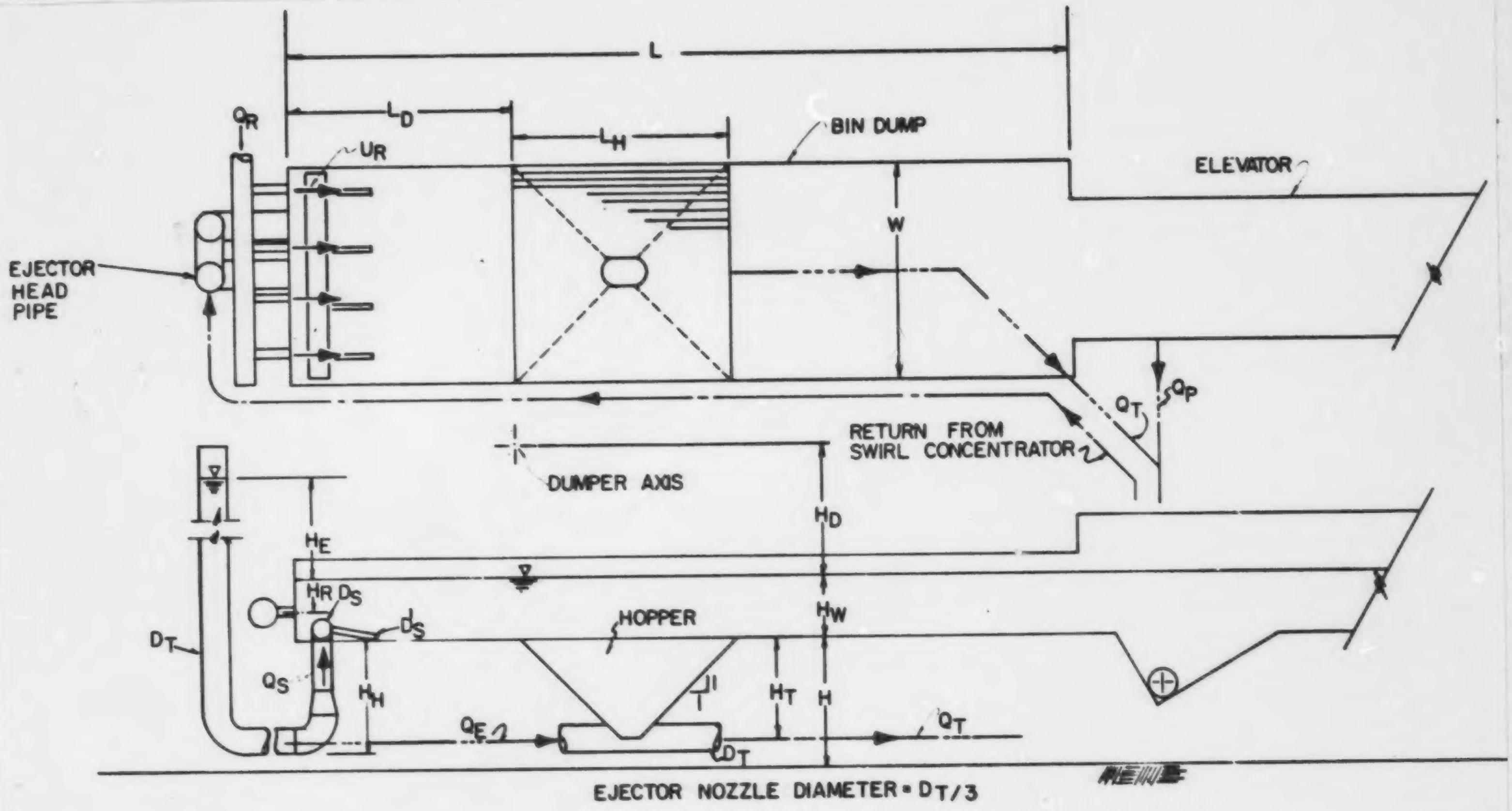
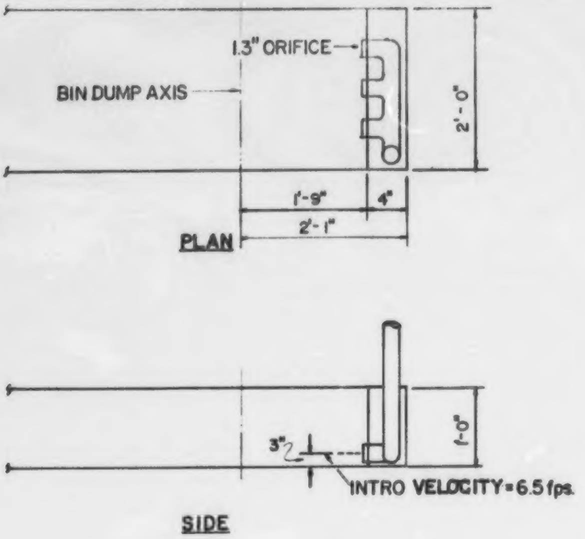
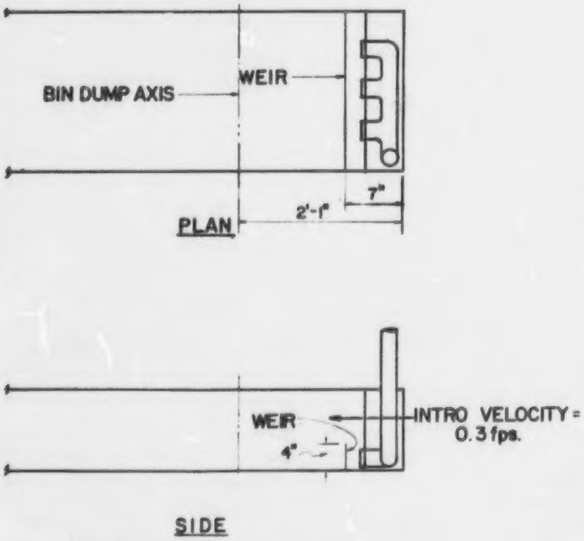

L
L_D
L_H
Q_R
U_R
BIN DUMP
ELEVATOR
EJECTOR HEAD PIPE
W
Q_T
Q_P
RETURN FROM SWIRL CONCENTRATOR
DUMPER AXIS
H_E
H_D
H_R
D_S
D_S
H_W
HOPPER
D_T
Q_S
H_H
H_T
H
Q_E
D_T
Q_T
EJECTOR NOZZLE DIAMETER = D_T/3

FIG. 2 MODEL BIN DUMP DESIGN PARAMETERS


1.3" ORIFICE
BIN DUMP AXIS
2'-0"
1'-9"
4"
2'-1"
PLAN
3"
1'-0"
INTRO VELOCITY=6.5 fps.
SIDE

(a) JET FLOW RETURN


BIN DUMP AXIS
WEIR
7"
2'-1"
PLAN
WEIR
4"
INTRO VELOCITY = 0.3 fps.
SIDE

(b) WEIR FLOW RETURN

FIG. 3 ALTERNATIVE RECIRCULATED WATER RETURNS

Soils selected for evaluation of deposition patterns were Yolo Loam and Hanford Sandy Loam. The characteristics of these two soils are summarized in Table 2. Hanford Sandy Loam is predominantly a sandy material, whereas Yolo Loam contains a significant amount of clay. It was anticipated that the normal deposition patterns would depend both on soil type and method of water recirculation through the dump tank, therefore each soil type with each combination of recirculated water introduction into the bin dump tank was evaluated.

TABLE 2

STUDY SOIL COMPOSITIONS

	AVERAGE WEIGHT PERCENT	
COMPONENT	YOLO LOAM	HANFORD SANDY LOAM
Sand	22.5	74.5
Silt	50.0	16.0
Clay	27.5	9.5

Throught the soil deposition studies, flows were made of the conventional recirculation type. Flow rates were calibrated based upon clear water flowing through the jets. Pressure drop across the jetted nozzles was determined with a water manometer. This head was maintained throughout the studies. Due to the material contained in the soils, it was not practical to run the in-line water meter with the dirty water. Therefore, overflows from the bin dump were monitored volumetrically to check the calibrated flow.

Once a steady flow had been established, the bin dump loading was simulated with a scaled model of tomato bins containing 2" x 4" wood blocks with a water displacement volume approximately equal to tomatoes. Soil was introduced into each bin at approximately 5% of modeled raw product weight, or 8 lbs. of soil per bin. The soil was sprinkled throughout the bin to simulate actual operation.

Bins were dumped at regular intervals with the direction of bin dump rotation alternating from one dump sequence to the next as was done in the full scale operation. Figures 4 and 5 illustrate the simulated dump operation.

Turbidity measurements of the supernatant were made before and after the loading operation sequence. A complete loading operation consisted of 15 dumps or 120 lbs. of soil. After the completion of an operations sequence, the depth of settled material in the base of the bin dump was measured to determine the solid water interface below the water surface. These measurements allowed determination of the distribution of the soil deposition.

Photos of settled soil following drainage of the supernatant liquid provided an indication of the regular distribution of soil along the bin dump bottom. While it was originally planned to film the dump operation to convey the dynamics of soil deposition, the turbidity of the liquid prevented meaningful visual observations from being made.

The soil deposition patterns noted provided a basis for locating the false bottom with the solids collection hopper and hydraulic transport system. It was expected that soil deposition patterns would be such as to indicate optimum location of the hopper for removal of 90% of the accumulated settled material. The basic configuration of the collection and transport system was to remain as illustrated in Figure 2.

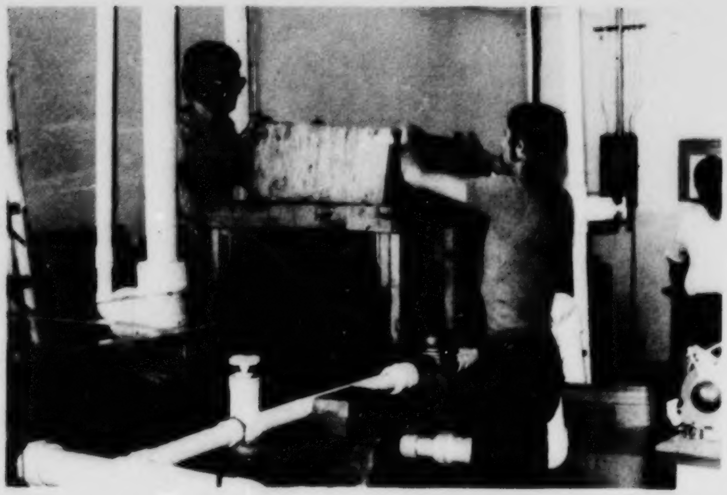
The objective was to determine the collection efficiency of the designed false bottom and transport system. It was expected that removal of the major portion of the deposited solids on the bin dump bottom would significantly alter turbulence pattern throughout the bin dump. The effect this would have on the collector efficiency was to be determined by the tests.

In addition to the efficiency observations, sufficient flexibility was designed into the solids collection and transport system to vary certain characteristics. These characteristics are summarized in Table 3. The direction of the false bottom open slots was expected to affect the solids collection efficiency as well as the drag experienced by the recirculated bin dump flow. Thus, the system operated with slots running transverse and parallel to the direction of flow.

The major objective of the model study was to develop quantitative design criteria for scaling the solids collection and transport system to a full scale bin dump operation. Using the results of the model bin dump study, and the Froude Number similarity, design criteria can be scaled to any bin dump operation.

FULL SCALE WATER RECYCLE SYSTEM

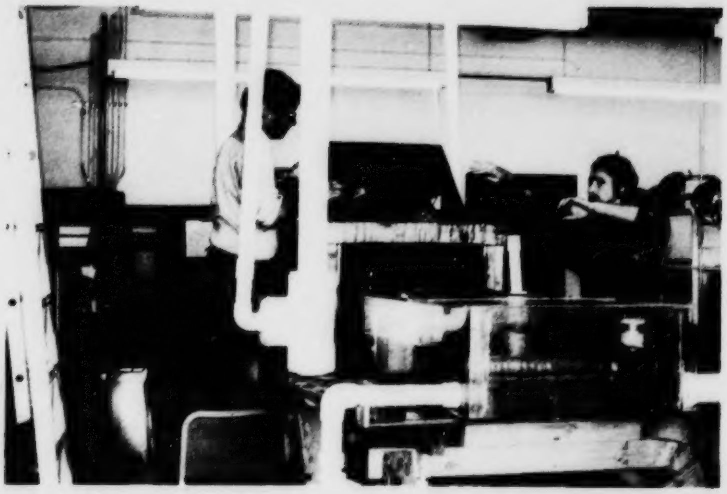
As a result of the model scale study, the design for the full scale system was modified. Figure 6 is a flow schematic of the improved water recycle system. The key elements involved were the false bottom, ejector solid transport, screen and solids discharge hopper, swirl concentrator, sludge thickener, and chemical flocculation system. In this design, the



PLACING LOADED BIN ON DUMPER FRAME

FIGURE 4

FIGURE 5



DUMPING SOIL AND PRODUCT

TABLE 3

COLLECTION AND TRANSPORT SYSTEM VARIABLES (1)

1.	Ejector Motive Flow, Q_E	Determine ejector motive flow which prevents accumulation of soil in hopper.
2.	Pumped/Motive Flow Ration Q_S/Q_E	Determine pumped flow preventing accumulation of soil in hopper.
3.	False Bottom Open Area	Determine open area required which prevents soil accumulation in bin dump.

(1) Tests conducted with each soil composition.

settleable soil solids were removed from the system by the false bottom and the ejector solid transport mechanism. The solids were transported to a gravity screen for separation of vine, rock, and debris. The solids within the underflow from the swirl concentrator were further concentrated within the sludge thickener. The overflow from the swirl concentrator was returned to the bin dump as recycle water. These facilities are shown in Figures 7 and 8.

The intake pumping system consisted of a take-off structure in the base of the dump from which an in-line ejector transported the soils solids to the soil water handling pump as shown in Figure 9. The take-off structure consisted of a 2' x 4' bar screen with approximately 3/4" openings which was located right at the bottom of the dump where the tomatoes were introduced. Based on the model study conducted by EUTEK (4), more than 80% of the settleable soil solids entering with the product could be collected and transported by providing a false bottom and ejector transport mechanism. It was also determined that the ejector transport mechanism worked in a reliable and consistent manner in removing accumulated soil solids from the hopper of the false bottom. The false bottom and ejector transport system basically allowed the removal of the bulk of settleable soil solids from the bin dump without significantly altering the product flow within the bin dump. Thus, the major disadvantages associated with the scour jet system were overcome.

The motive force to the in-line ejector was provided by the returned supernatant from the swirl concentrator, located approximately 15' above the in-line ejector. A special type of pump which could pump grit and sand continuously without serious maintenance problem during the operational period was used.

Gravity Screen and Swirl Concentrator

Soil laden water was pumped to a gravity screen from which vines, tomato seeds and other debris were separated from the water. The separated materials fell into a screen solids discharge hopper. The "debris-free" water flowed by gravity into a swirl concentrator, which was of simple annular shaped construction and required no moving parts. Figure 10 shows a close view of the swirl concentrator. Grit and sand in the incoming wastewater was separated in this unit by swirl action. The orifice size of the underflow from the swirl concentrator controlled the underflow rate. In this design, the maximum underflow rate was 100 gpm and the maximum designed incoming flow rate was about 500 gpm. Therefore, the overflow rate which returned to the bin dump through the scouring ejectors was approximately 400 gpm. The liquid level, in the largest of three pipe columns shown in Figure 11, provided potential energy, which became the motive force, to the scouring ejectors upstream of the bin dump. The flow from

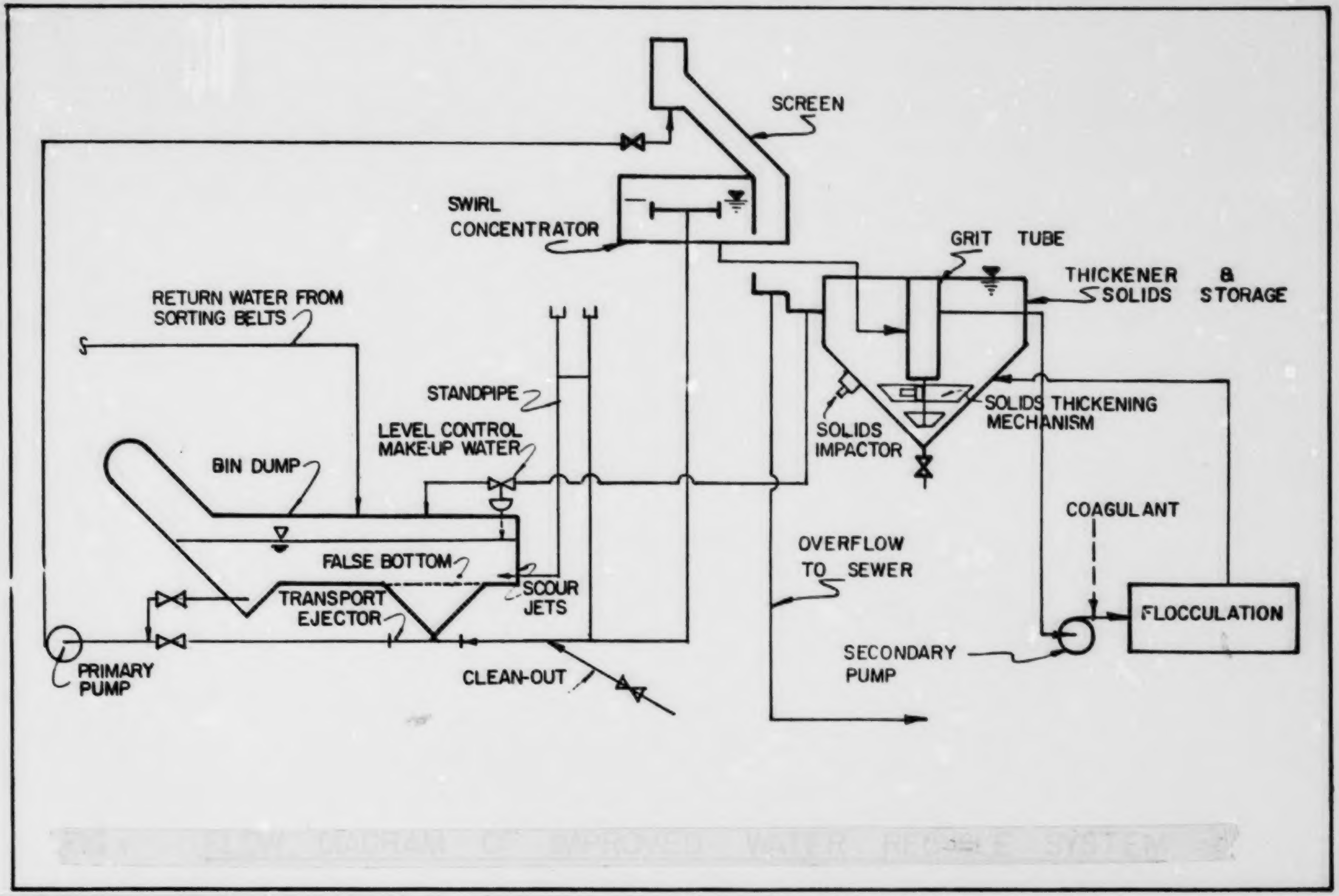
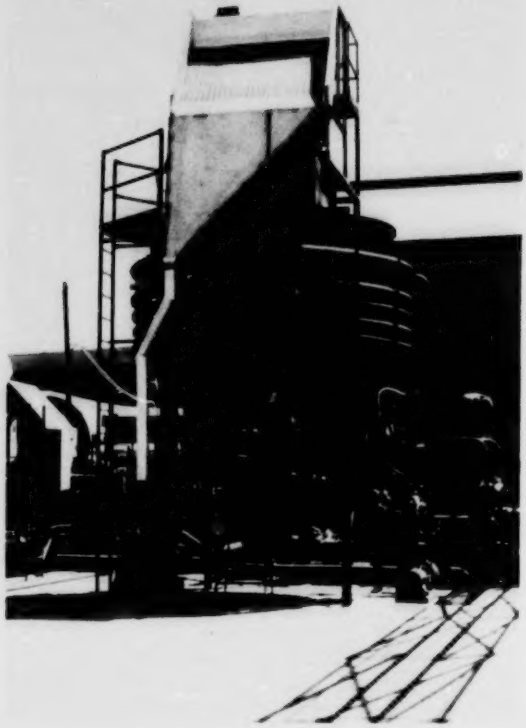

SCREEN
SWIRL CONCENTRATOR
GRIT TUBE
THICKENER & SOLIDS STORAGE
RETURN WATER FROM SORTING BELTS
STANDPIPE
SOLIDS THICKENING MECHANISM
LEVEL CONTROL MAKE-UP WATER
SOLIDS IMPACTOR
BIN DUMP
COAGULANT
FALSE BOTTOM
OVERFLOW TO SEWER
TRANSPORT EJECTOR
SCOUR JETS
FLOCCULATION
PRIMARY PUMP
CLEAN-OUT
SECONDARY PUMP

FIG. 6 FLOW DIAGRAM OF IMPROVED WATER RECYCLE SYSTEM

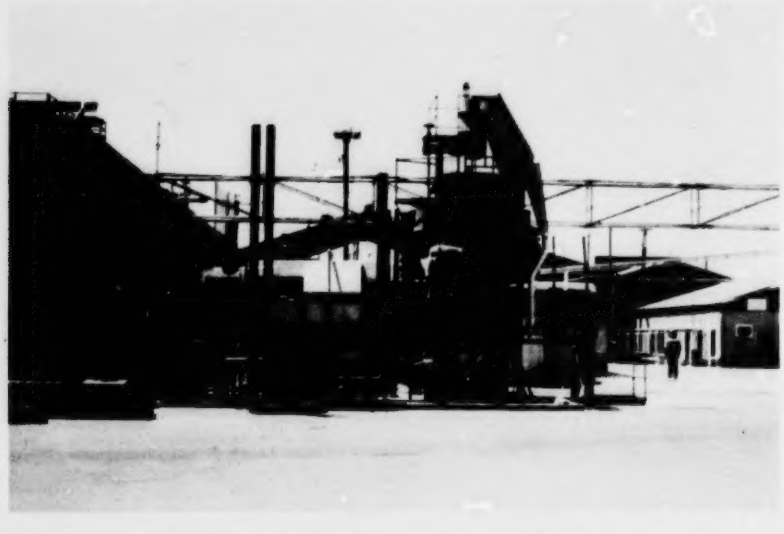
CW:
CORRECT
this

FIGURE 7



VIEW OF IN–TAKE PUMP, SCREEN, SWIRL CONCENTRATOR, SLUDGE THICKENER AND TUBE FLOCCULATOR

FIGURE 8



GENERAL VIEW OF WATER RECYCLING FACILITIES

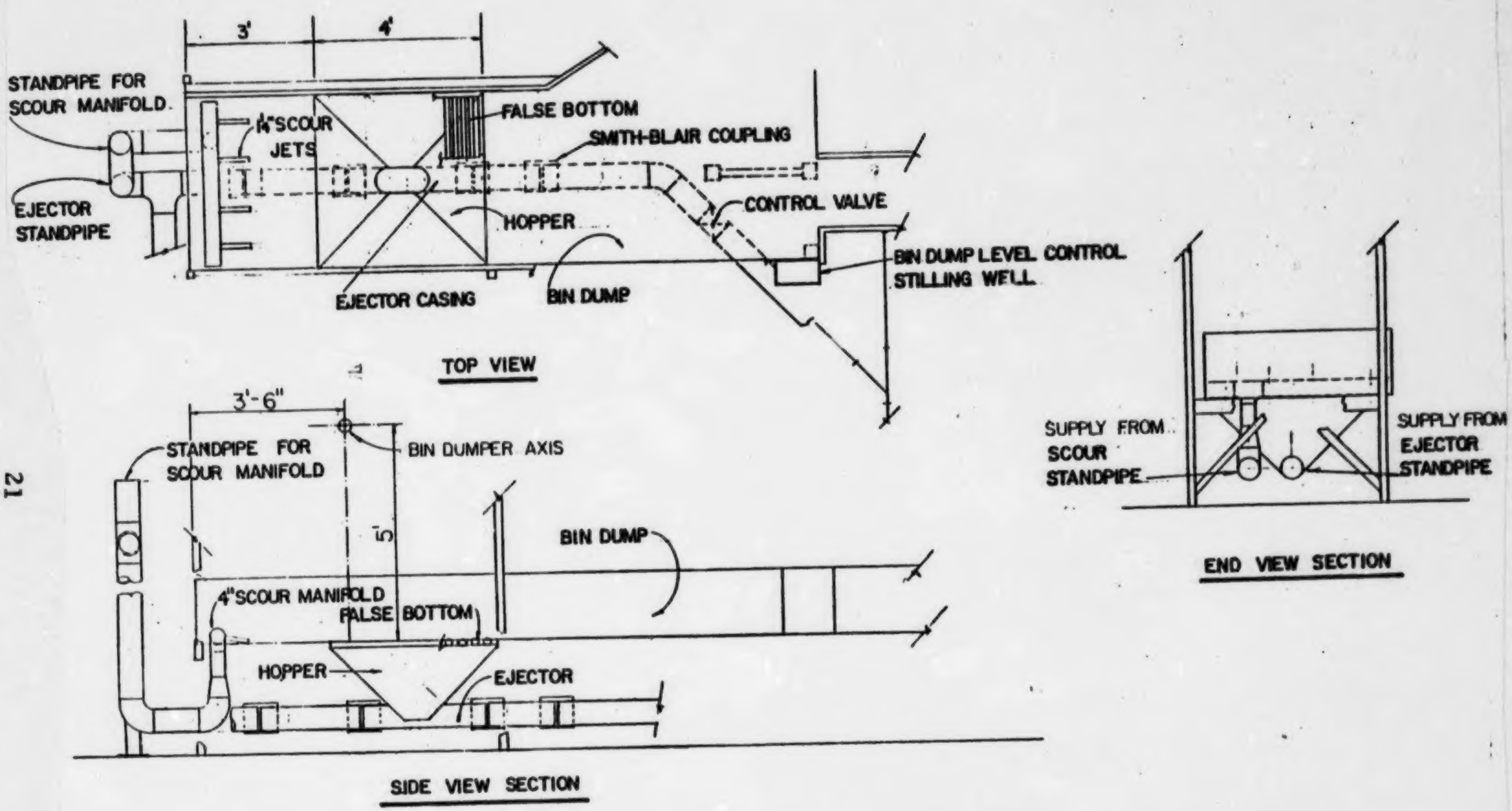

3'
4'
STANDPIPE FOR SCOUR MANIFOLD.
1/4"SCOUR JETS
FALSE BOTTOM
SMITH-BLAIR COUPLING
EJECTOR STANDPIPE
CONTROL VALVE
HOPPER
BIN DUMP LEVEL CONTROL STILLING WELL
EJECTOR CASING
BIN DUMP
TOP VIEW
3'-6"
STANDPIPE FOR SCOUR MANIFOLD
BIN DUMPER AXIS
5'
BIN DUMP
4"SCOUR MANIFOLD
FALSE BOTTOM
HOPPER
EJECTOR
SIDE VIEW SECTION
SUPPLY FROM SCOUR STANDPIPE
SUPPLY FROM EJECTOR STANDPIPE
END VIEW SECTION

FIG.9 FULL SCALE GRIT COLLECTOR & TRANSPORT SYSTEM DESIGN

these scouring ejectors provided the momentum for transporting the tomato downstream.

The 10 foot diameter gravity thickener tank provides a two hour quiescent environment in which solids from the swirl concentrator underflow could be separated and thickened for subsequent withdrawal. The overflow rate from the thickener tank was approximately equal to the swirl concentrator underflow rate. This prevented overflows from occurring from the bin dump and assured a single overflow point from the water recycle system to the sewer. Depending on the liquid level in the dump tank, a portion of water not returned to the dump tank was discharged to the sewer. Only treated and clarified water was discharged into the sewer.

The center pipe column shown in Figure 11 provided a conduit for recycling thickener overflow back to the bin dump, and the pipe column at the left was for discharging to the sewer. The center box shown in the same figure was a split box regulating the level of flow which discharged to the sewer.

In order to increase the solids concentrations discharged from the solids thickener, a thickening device was required. While the first conclusion was to install a mechanical rake, as is conventionally done in such thickeners, a mechanical device with either chain or gear drive would have operated below the water surface and thus would have been difficult to reach for maintenance purposes. In addition, being exposed to the elements throughout most of the year would perhaps be a less than desirable approach to thickening of solids. Hence, a thickening vein was installed which acted upon a vibratory principle to break down bridging of solids within the thickening zone. The thickening vein was activated by pneumatic impactors. In addition to the internal impactor, an external impactor was mounted on the cone of the thickener to assist in achieving flow of solids down the walls to the cone apex as shown in Figure 12.

This pneumatic impactor provided impacts at a 60-psi pressure to the sludge thickener base on a controlled time interval. Settled sludge was removed from the thickener periodically by opening a 6" gate valve and the withdrawn sludge was collected in a gondola for disposal.

A Sabre controller coupled with the coagulant pump and a turbidimetric sensor was installed to proportionally control coagulant dose with sensed turbidity. The water recycle pump and chemical feed pump are shown in Figure 13.

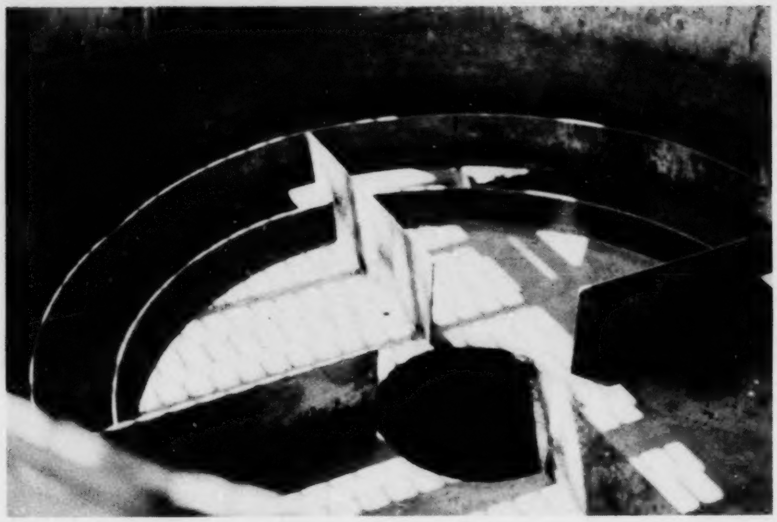


FIGURE 10 - Close-up View of Swirl Concentrator

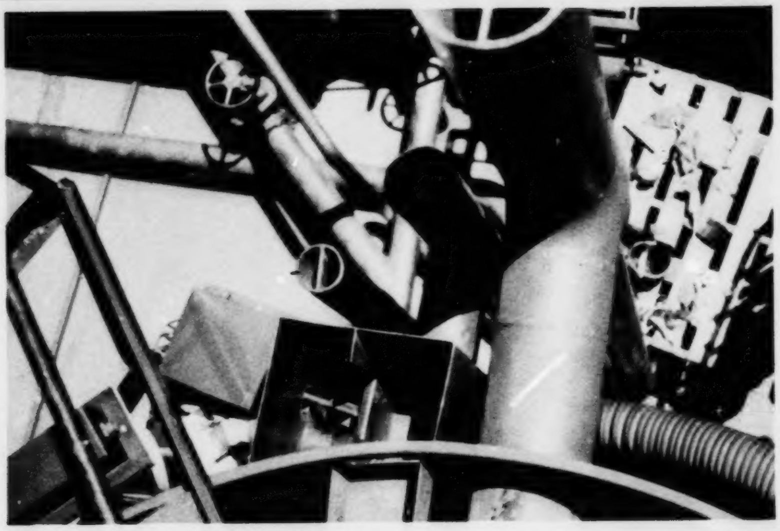


FIGURE 11 - Close-up View of Liquid Level Controller

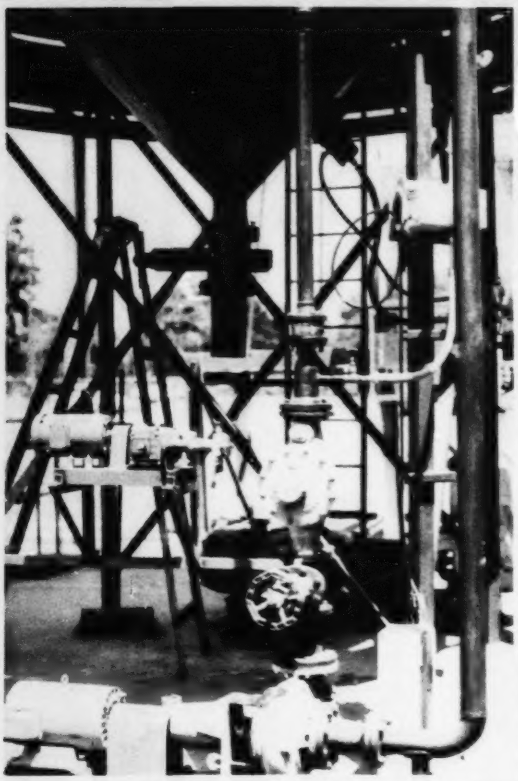


FIGURE 12

View of Water Recycling Pump and Chemical Feeding Pump

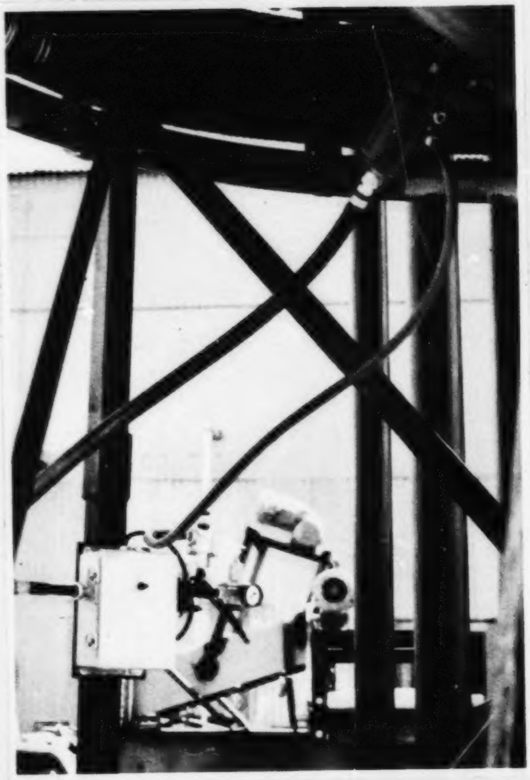


FIGURE 13

Close View of Impact Vibrator

WATER USE SYSTEM

Conventional Washing System

The conventional washing system consisted of four washing steps; dump tank, inside washer flume, distribution flume, and final rinse step. As shown in Figure 14, the washing water was directed counter-current to the direction of the tomato. Excess water in the distribution flume and tank 3 was pumped to the inside washer flume. Similarly, excess water from the inside washer flume flowed by gravity to tank 1. An internal recycling loop exists between tank 1 and the dump tank. Consequently, in each consecutive step a higher quality of washing water existed. In the counter-current tomato washing system a significant saving in water consumption was realized. It should be noted that the conventional washing system, adopted in this study, used water recycle and, therefore, was not the same as "conventional" washing systems commonly employed.

Conventional Washing with Water Recycling System

Due to difficulty in the start-up of the rubber disc cleaner, the mode of operation was changed to evaluate the efficiency of conventional washing with water recycle. Tomatoes coming into the plant were processed in the same manner as previously described. The only difference, as compared to the first mode of operation, was incorporation of the swirl concentrator into the water recycle system. The steel plate originally placed over the top of the false bottom was removed. Soil solids passed through the false bottom and were transported by an ejector transport mechanism to the swirl solids concentrator.

As shown in Figure 15, the overflow from the swirl concentrator returned to the dump tank. The underflow discharged to a sludge thickener for solids concentration. The supernatant from the sludge thickener was either returned to the dump tank or discharged to the sewer; the direction was determined by the pneumatically controlled liquid level controller located in the dump tank.

Figure 15 also shows the flow meter and sample collection points for the conventional washing system with water recycle. There were a total of ten meters monitoring the flow rate. In addition, there were a total of seven points from which composite samples were collected for water quality analysis. Soil solids from the dump tank and from the sludge thickener were collected for total solid concentration determinations.

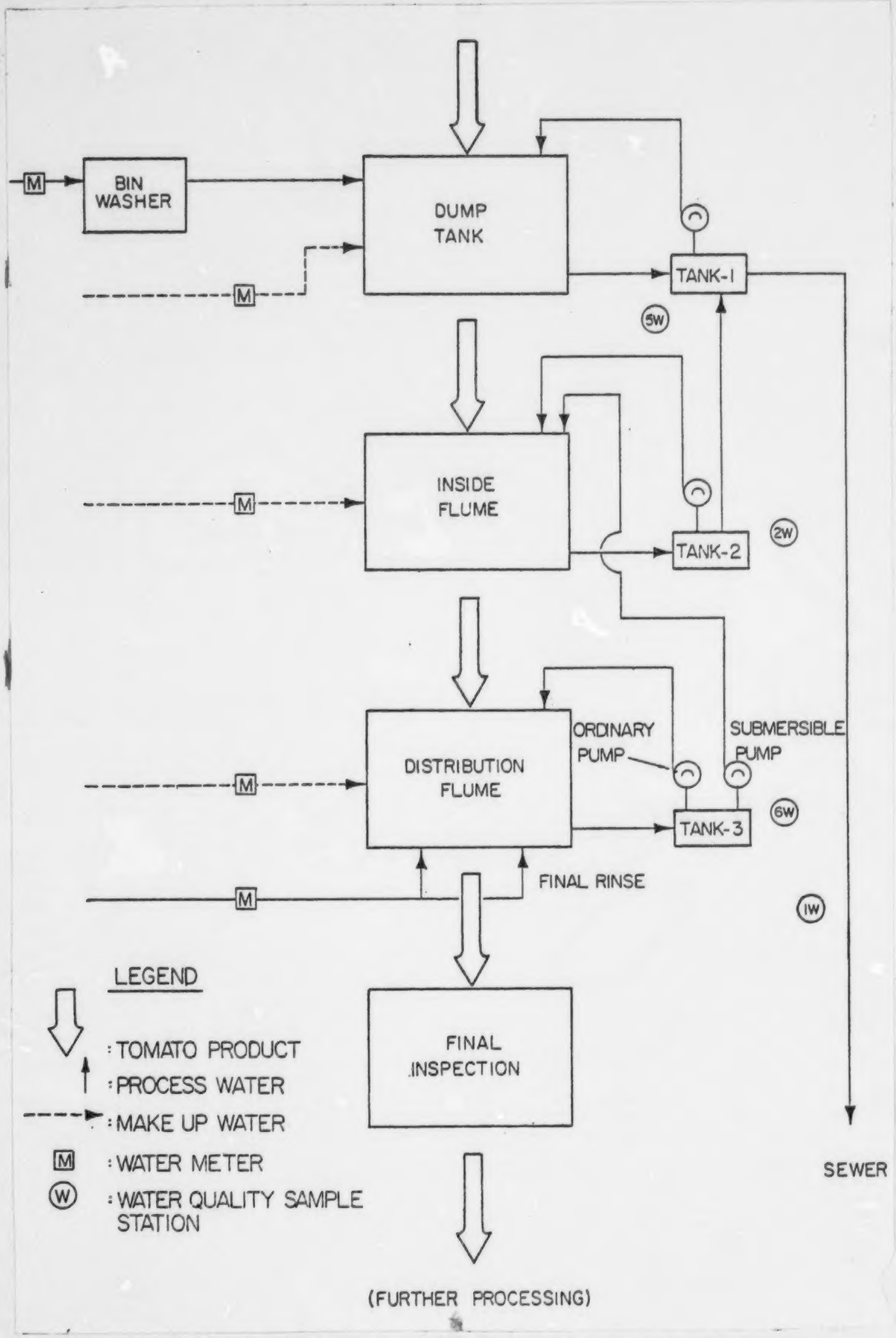

BIN WASHER
DUMP TANK
TANK-1
5W
INSIDE FLUME
TANK-2
2W
DISTRIBUTION FLUME
ORDINARY PUMP
SUBMERSIBLE PUMP
TANK-3
6W
FINAL RINSE
1W
FINAL INSPECTION
SEWER
(FURTHER PROCESSING)
LEGEND
: TOMATO PRODUCT
: PROCESS WATER
: MAKE UP WATER
M : WATER METER
W : WATER QUALITY SAMPLE STATION

FIG. 14 FLOW DIAGRAM OF CONVENTIONAL CLEANING SYSTEM

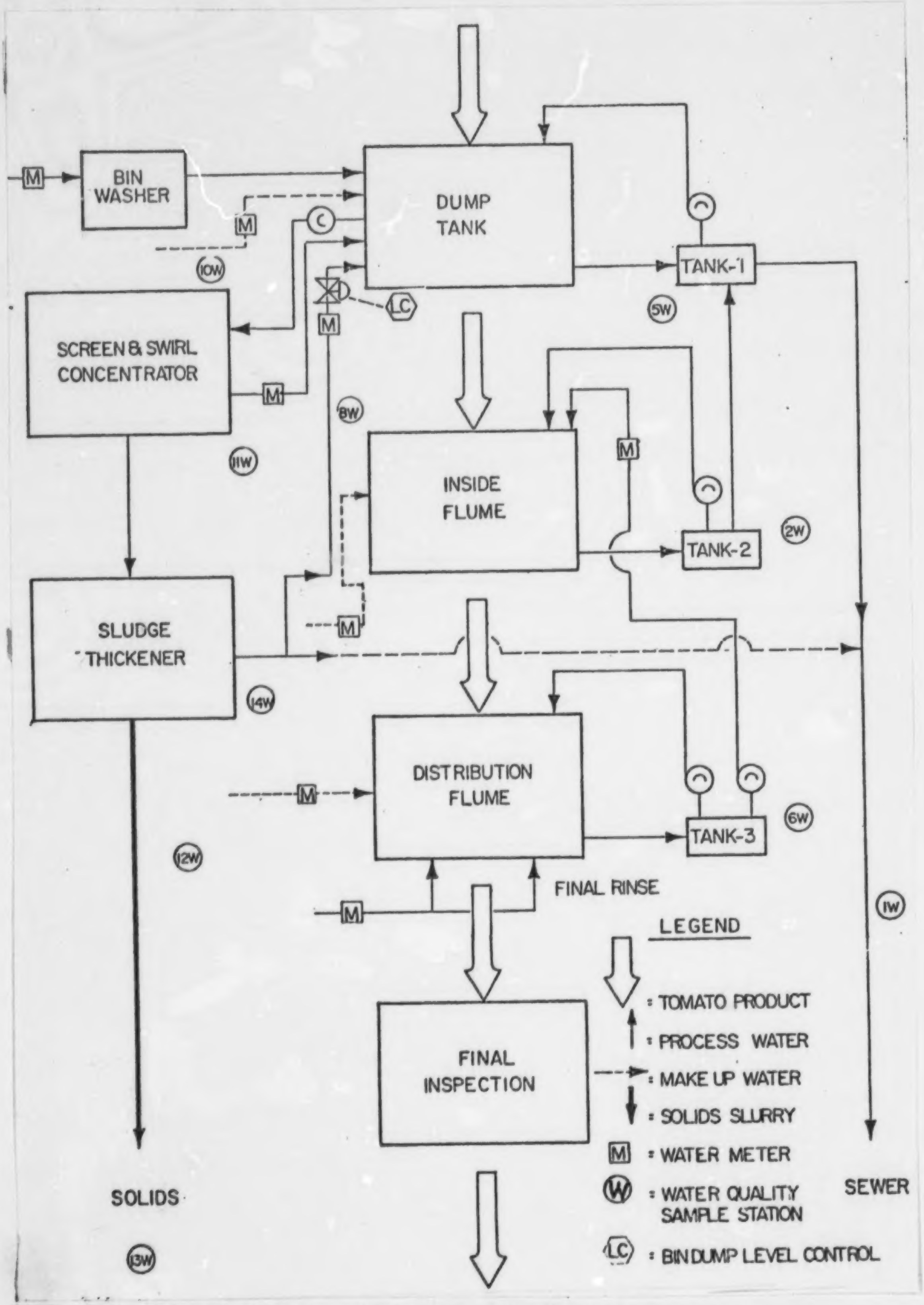

BIN WASHER
DUMP TANK
M
C
10W
LC
M
5W
TANK-1
SCREEN & SWIRL CONCENTRATOR
M
8W
11W
INSIDE FLUME
M
TANK-2
2W
SLUDGE THICKENER
M
14W
DISTRIBUTION FLUME
M
TANK-3
6W
12W
M
FINAL RINSE
1W
LEGEND
: TOMATO PRODUCT
: PROCESS WATER
: MAKE UP WATER
: SOLIDS SLURRY
M : WATER METER
W : WATER QUALITY SAMPLE STATION
LC : BIN DUMP LEVEL CONTROL
FINAL INSPECTION
SOLIDS
13W
SEWER

FIG. 15 FLOW DIAGRAM OF CONVENTIONAL CLEANING WITH WATER RECYCLE SYSTEM

Disc Cleaner with Water Recycling System

In this mode of operation, tomatoes were transported directly from the dump tank to rubber disc cleaner and subsequently transported into a distribution flume and to a final inspection stage as shown in Figure 16. The solids trapped in the false bottom were transported by an ejector solids transport mechanism to the gravity screen and the swirl concentrator for further separation of solids.

The rubber disc cleaner provided an alternative method of cleaning (6). It replaced the flumes and sprays used in the conventional cleaning process. The unit was approximately 10 ft. long and 5 ft. wide. Discs of $4\frac{1}{4}$ inch diameter were mounted on a $\frac{1}{2}$ inch stainless steel shaft. Rubber discs were 7/8 inch thick to a radius of 3/4 inch narrowed down to $\frac{1}{4}$ inch for the next 5/8 inch radius, then narrowed to 1/32 inch for the outer 3/4 inch of radius. Shafts were parallel to each other and 3 inches apart, thereby providing $1\frac{1}{4}$ inch overlap between staggered rows of discs. The discs rotated in the direction of product movement. Two small whirl jet spray nozzles provided full coverage of the 5 ft. wide disc bed. Rinse water was collected and pumped to the swirl concentrator for further solids separation.

Figure 16 illustrates the flow diagram, flow meter locations and sample points. There were only two internal recirculating loops, one at the dump tank and one at the distribution flume. The pneumatically operated liquid level controller, in the dump tank, regulated the return overflow from the thickener. Supernatant from the thickener was the only water discharged to the sewer. As indicated in the figure, excessive flow from tank 2, equivalent to the make-up in the distribution flume, was returned to the dump tank for reuse.

Disc Cleaner with Water Recycle and Chemical Flocculation

For this mode of operation the flow diagram was similar to the previous flow scheme. Added was an internal chemical coagulation and flocculation step, as shown in Figure 17. The primary objective of this mode of operation was to evaluate the effectiveness of chemical coagulation for soil solids removal and the improved quality of water discharged to the sewer. In this mode of operation, a chemical coagulant was injected into a portion of the thickener overflow and the flocculation was accomplished in the tube flocculator. Flocculated solids were returned to the opposite side of the thickener.

The chemical coagulation-flocculation sybsystem consisted of four components; 1) recirculation pump, 2) tube flocculator, 3) slip-stream turbidimeter, and 4) chemical feed mechanism. A 125 gpm recirculation pump withdrew water and circulated it through the tube flocculator. A

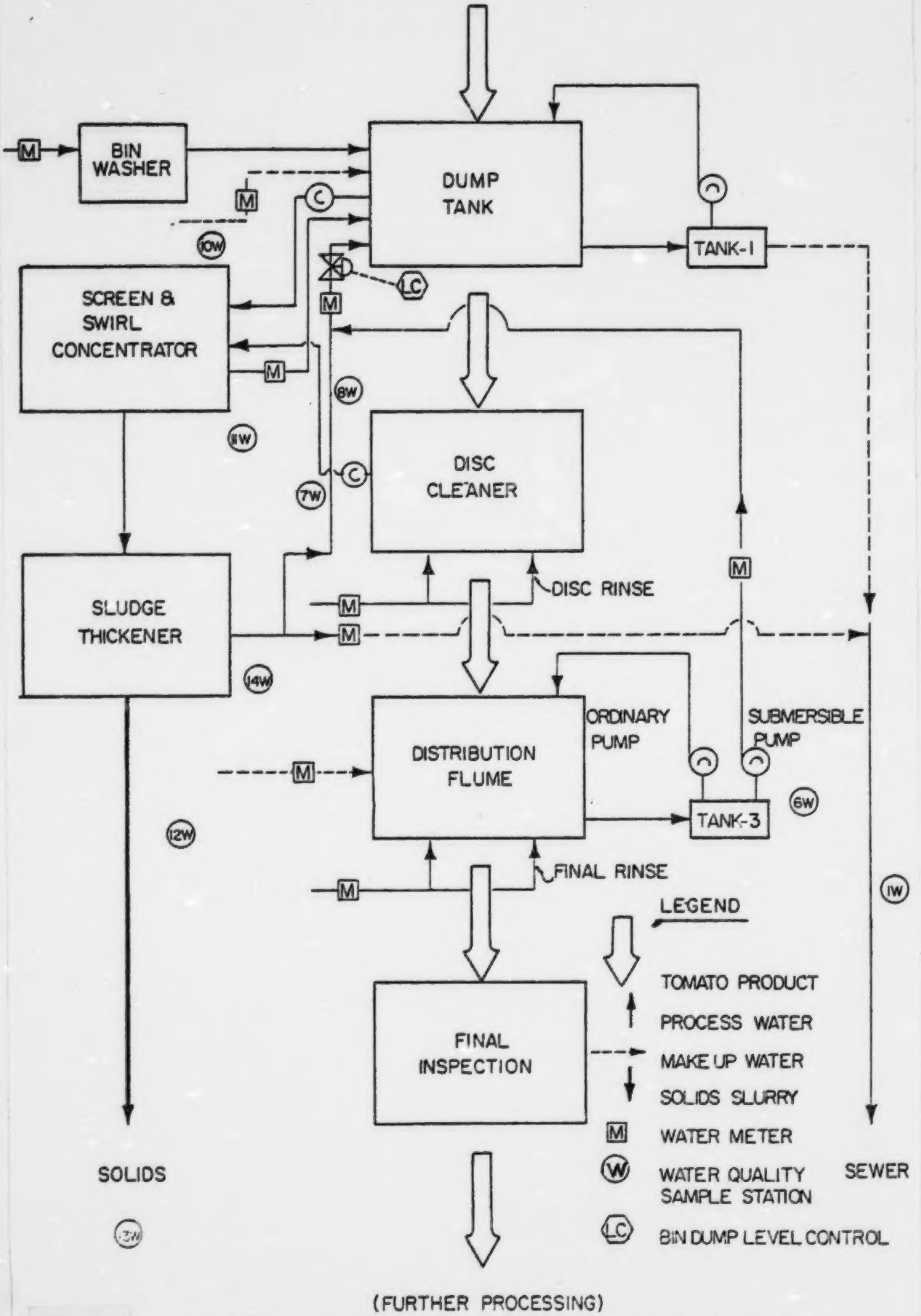

M
BIN WASHER
DUMP TANK
M
C
10W
TANK-1
LC
SCREEN & SWIRL CONCENTRATOR
M
M
8W
11W
DISC CLEANER
C
7W
SLUDGE THICKENER
M
DISC RINSE
M
M
14W
DISTRIBUTION FLUME
ORDINARY PUMP
SUBMERSIBLE PUMP
M
TANK-3
6W
12W
M
FINAL RINSE
1W
LEGEND
TOMATO PRODUCT
PROCESS WATER
MAKE UP WATER
SOLIDS SLURRY
M WATER METER
W WATER QUALITY SAMPLE STATION
LC BIN DUMP LEVEL CONTROL
FINAL INSPECTION
SOLIDS
SEWER
3W
(FURTHER PROCESSING)

FIG. 16 FLOW DIAGRAM OF DISC CLEANER WITH WATER RECYCLE SYSTEM

portion of the flow was directed into a slip-stream turbidimeter which continuously monitored the turbidity of the water. An electrical circuit was set up so that the chemical feed pump could be automatically controlled by the turbidity of the water. A graphical determination of chemical feed rates and chemical dosages is shown in Figure 18. The desired amount of chemical feeding rate was determined from jar tests and controlled by setting the calibrated feed pump.

Coagulation and flocculation were accomplished in the tube flocculator (7), consisting of a series of discreet pipe sections coiled around the outer wall of the thickener. Each downstream section had a progressively larger diameter and length with diverging transition members connecting to adjacent sections. The radius of curvature of the coil was predetermined so that the velocity gradient and flow conditions throughout the length of the pipe would yield optimum coagulation-flocculation. This flocculator was capable of carrying the water and chemical mix from a relatively high pressure head to a relatively low pressure head, enhancing floc growth.

Tomato Cleaning

For the conventional system tomato samples were collected from the following locations and evaluated for cleanliness:

1. Bin before dumping = 1P
2. After the dump tank = 2P
3. After the combined inside washer = 3P
4. After final rinse = 4P

Tomato samples from the demonstration system were collected from the following locations:

1. Bin before dumping = 1P
2. After the dump tank = 2P
3. After the disc cleaner = 3P
4. After final rinse = 4P

Every four hours approximately 5 pounds of tomatoes were collected from the four sampling locations of either the conventional or the demonstration system. Tomatoes were weighed and water equal to twice the weight was added to a plexiglass cylinder. Tomatoes were placed in a wire

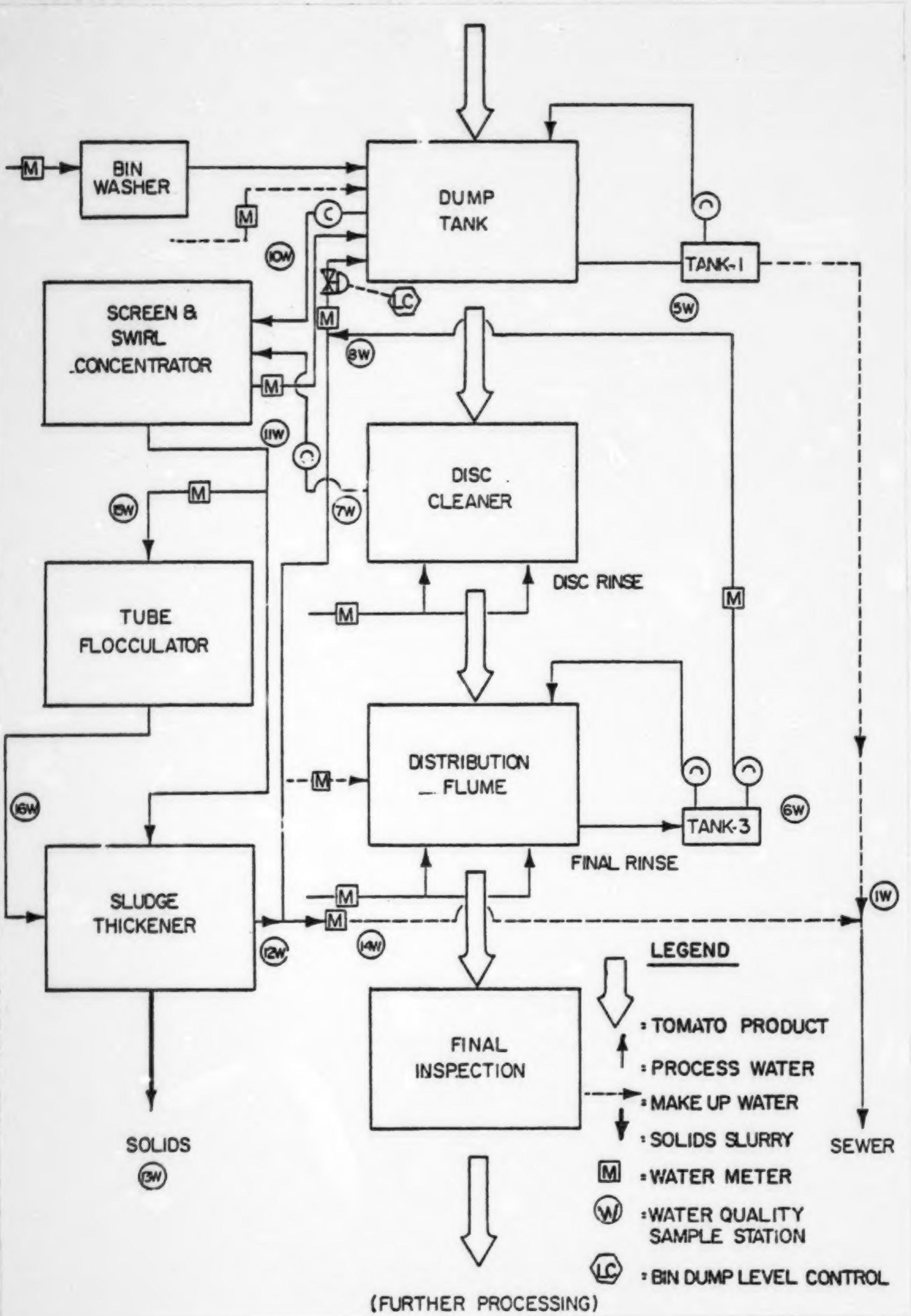

BIN WASHER
M
DUMP TANK
C
10W
LC
TANK-1
5W
SCREEN & SWIRL CONCENTRATOR
8W
11W
DISC CLEANER
7W
15W
TUBE FLOCCULATOR
DISC RINSE
DISTRIBUTION FLUME
TANK-3
6W
16W
SLUDGE THICKENER
FINAL RINSE
1W
12W
14W
FINAL INSPECTION
SOLIDS
13W
SEWER
(FURTHER PROCESSING)
LEGEND
= TOMATO PRODUCT
= PROCESS WATER
= MAKE UP WATER
= SOLIDS SLURRY
M = WATER METER
W = WATER QUALITY SAMPLE STATION
LC = BIN DUMP LEVEL CONTROL

FIG. 17 17 FLOW DIAGRAM OF DISC CLEANER WITH WATER RECYCLE SYSTEM WITH FLOCCULATION

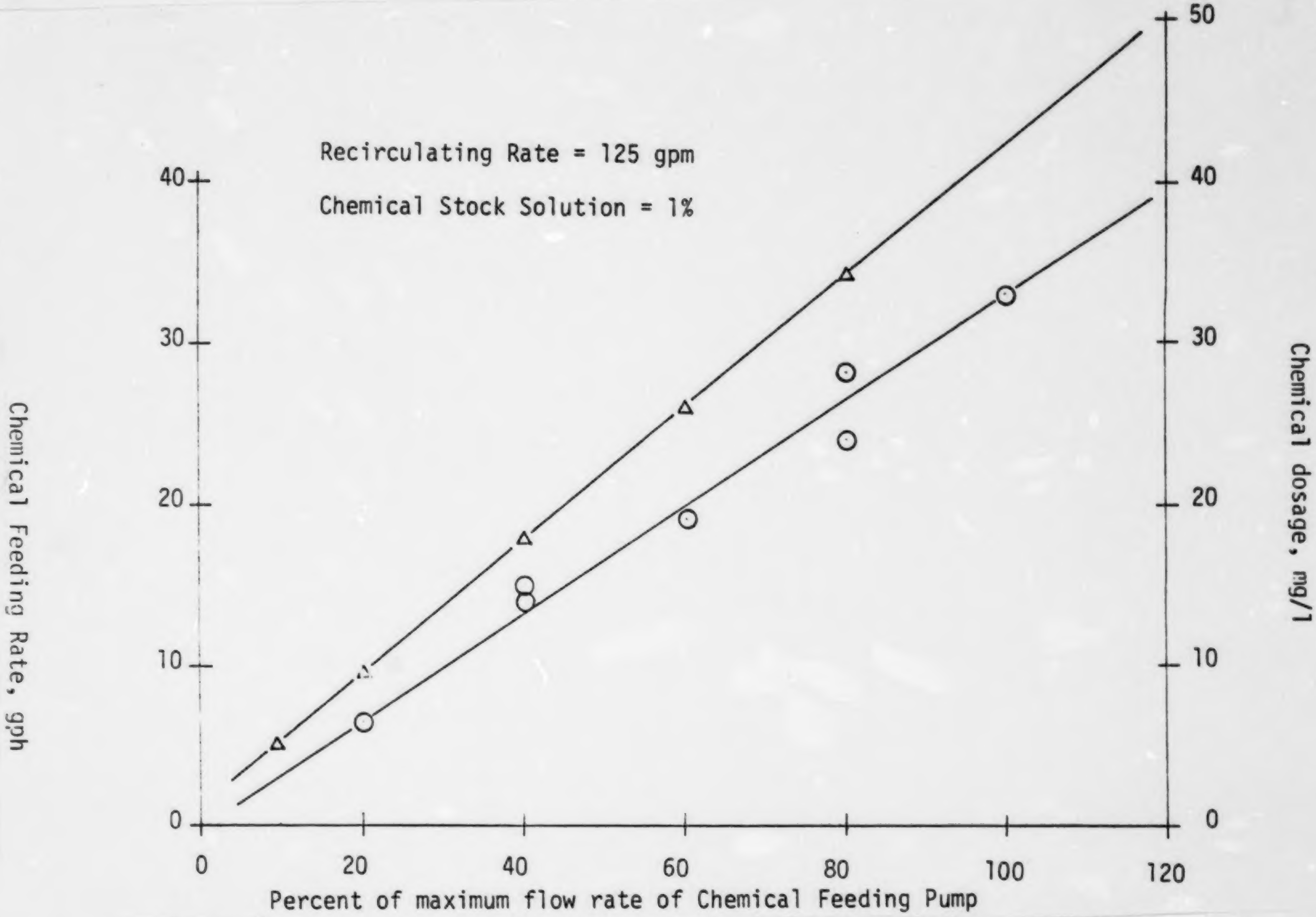


FIG. 18' GRAPHICAL DETERMINATION OF CHEMICAL FEEDING RATES AND CHEMICAL DOSAGES

32

mesh basked that was then placed in the cylinder. After shaking the basket for 2 minutes, it was removed and water from the cylinder was transferred to a sterile plastic bag and to a plastic quart bottle. Three 8 hour samples per 24 hours were obtained by combining two 4 hour samples three times a day.

All samples were held under refrigeration until transported to the Berkeley laboratory for analysis. Water in sterile plastic bags was analyzed for total plate count and mesophilic aerobic spores (8) and water in the plastic bottles was analyzed for suspended and fixed suspended solids (9).

Water samples were collected from the following locations:

1. Distribution flume overflow
2. Inside washes overflow
3. Dump tank overflow to gutter
4. Inside collection gutter
5. Disc cleaner effluent

Individual composite samples were collected from the above locations over a 24 hour basis with automatic timed samplers. Samples were analyzed for BOD, COD, suspended and fixed suspended solids (9).

VACUUM BELT MUD DEWATERING SYSTEM

In September of 1975, EUTEK designed, constructed and evaluated a low cost vacuum belt dewatering unit. The results of some limited testing were encouraging and there was a complete evaluation of this device during the 1976 season.

Figure 19 is a schematic drawing of the vacuum belt unit. The major components were:

1. Sludge receiving hopper and level control
2. Vacuum belt and chain drive
3. Vacuum source and filtrate pump
4. Filter cake removal and belt wash

Sludge from the thickener tank flowed by gravity into the hopper. The

33

rate of sludge discharging into the hopper was controlled by a valve. A sludge control level switch, mounted inside the hopper, regulated the volume of sludge. Sludge loading onto the belt was determined by the thickness of sludge applied to the belt and the rate of the belt speed.

Two types of belting material were evaluated:

1. Polypropylene monofilament, 6.4 oz/sq yd, porosity of 125 cfm at 20 inches Hg.

2. Nylon high twist, 8 oz/sq yd, porosity 40 to 70 cfm at 20 inches Hg.

The belt chain drive was powered by a $\frac{1}{2}$ hp motor with a variable speed drive. A Nash water seal vacuum pump, with a 2 hp motor operating at 1950 rpm, was used to maintain a vacuum. When operated at a vacuum of 36 inches of water, the vacuum pump pulled approximately 10 cfm of air through the belting material.

Sludge from the thickener tank was dewatered as it passed over the vacuum chamber. Filtrate was continuously removed by a diaphram pump. De-watered sludge cake was scraped from the belt and collected in a gondola. The vacuum belting material was washed by spray nozzles just prior to the sludge hopper.

The operational variables evaluated were:

1. Sludge solids loading rate

2. Type of belting material

3. Vacuum applied

4. Belt speed

5. Type and concentration of chemical for sludge conditioning

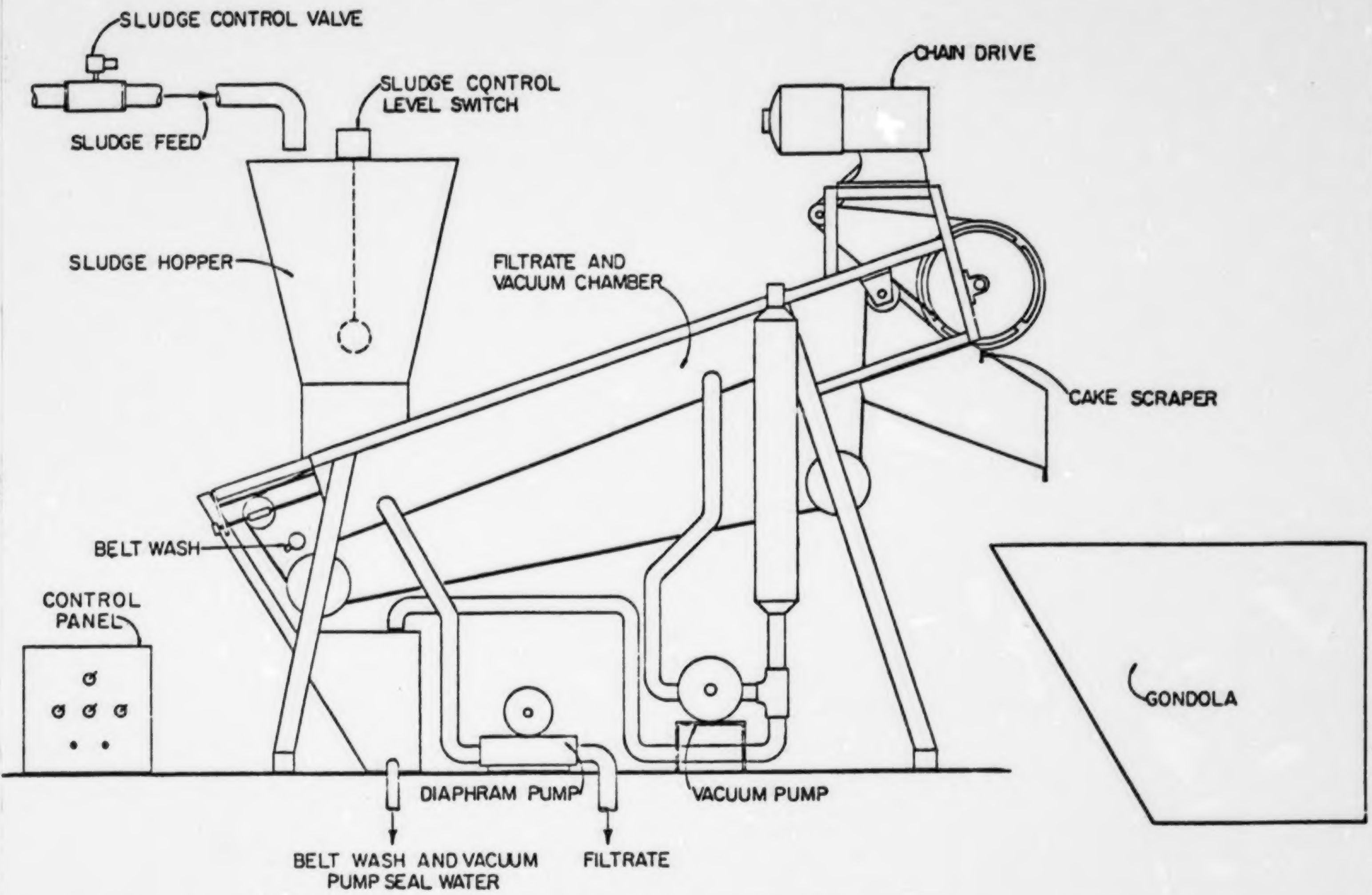

SLUDGE CONTROL VALVE
SLUDGE CONTROL LEVEL SWITCH
SLUDGE FEED
CHAIN DRIVE
SLUDGE HOPPER
FILTRATE AND VACUUM CHAMBER
CAKE SCRAPER
BELT WASH
CONTROL PANEL
GONDOLA
DIAPHRAM PUMP
VACUUM PUMP
BELT WASH AND VACUUM PUMP SEAL WATER
FILTRATE

FIG. 19 ASSEMBLY OF VACUUM BELT DEWATERING UNIT

SECTION 5

RESULTS AND DISCUSSION

MODEL STUDY

Test results in Figures 20 and 21 show the average depth and accumulated volume of soil deposition on the bottom of the bin dump for Yolo Loam. Figure 20 is for the loaded condition with the jet flow method of introducing recirculated flow and Figure 21 is for the condition of weir overflow method of introduction. There were no major differences in the distribution of the soil deposition under the two test conditions.

Soil deposition patterns for Hanford Sandy Loam are presented in Figures 22 and 23. The Hanford Sandy Loam did not develop the concentrated, settled condition experienced with Yolo Loam. This distribution pattern occured regardless of the method of introduction of the recirculated water flow. Another point observed with the Hanford Sandy Loam was the characteristic "humps" on the downstream side of the peak of the deposited solids. These humps or ripples were characteristic of the base of a scouring pile of sand and indicated accumulations of material which had been transported from the peak to the downstream side. The length of the distribution of the Hanford Sandy Loam parallels that of the Yolo Loam. This observation is somewhat supported by results in Figure 24, which shows the relative distances of transport for 10%, 50% and 90% accumulated volumes of the two soils. It should be noted that the most significant variation in the relative travel distance of the two soils occurred at the downstream end of the soil distribution pattern. This downstream effect further illustrated an effect of peak solids scour and transport with Hanford Sandy Loam.

Table 4 summarizes the critical dimensions noted for all deposition patterns and averages the results based on soil types. There was no significant difference in the deposition patterns with the two methods of recirculated water introduction.

Based on the pattern of soil deposition relative to the bin dumper axis and the fact that the major portion of the accumulated soil solids were immediately downstream of the bin dump axis, turbulence generated by the falling product from the bins had a more dominant effect on the soil

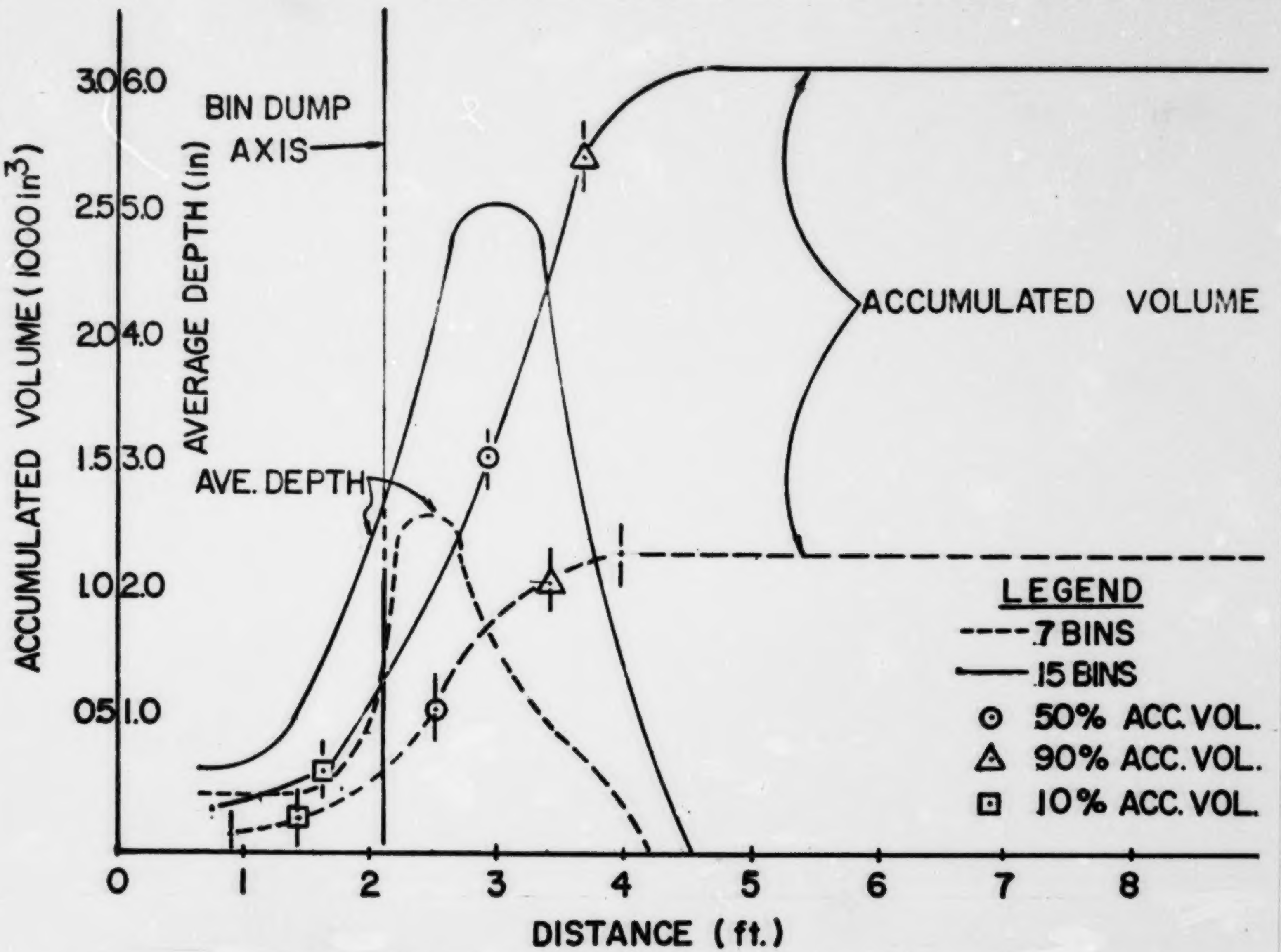


FIG. 20 SOIL DEPOSITION: YOLO LOAM-JET FLOW

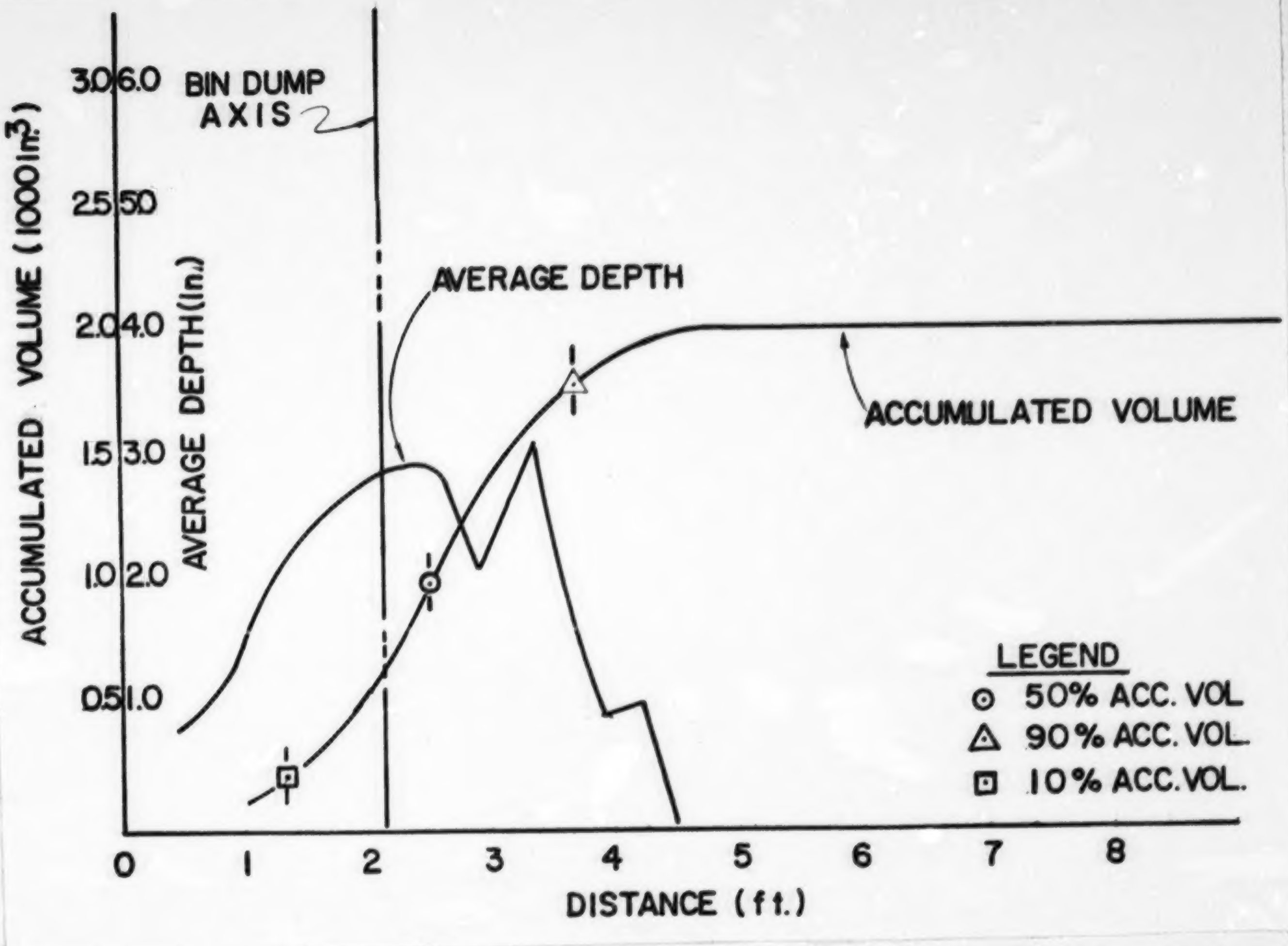


FIG. 21 SOIL DEPOSITION: YOLO LOAM-WEIR FLOW

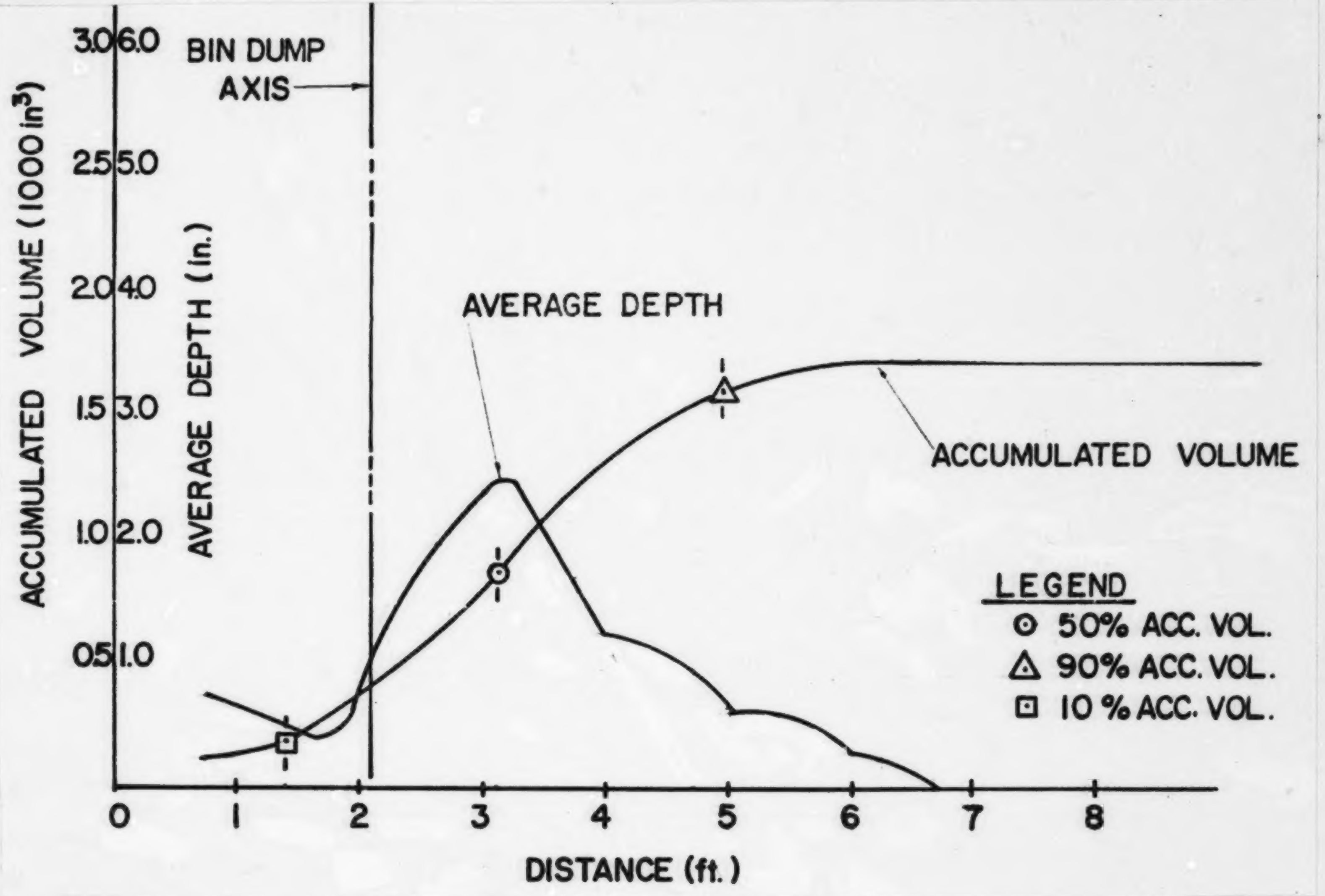


FIG. 22 SOIL DEPOSITION: HANFORD SANDY LOAM: JET FLOW

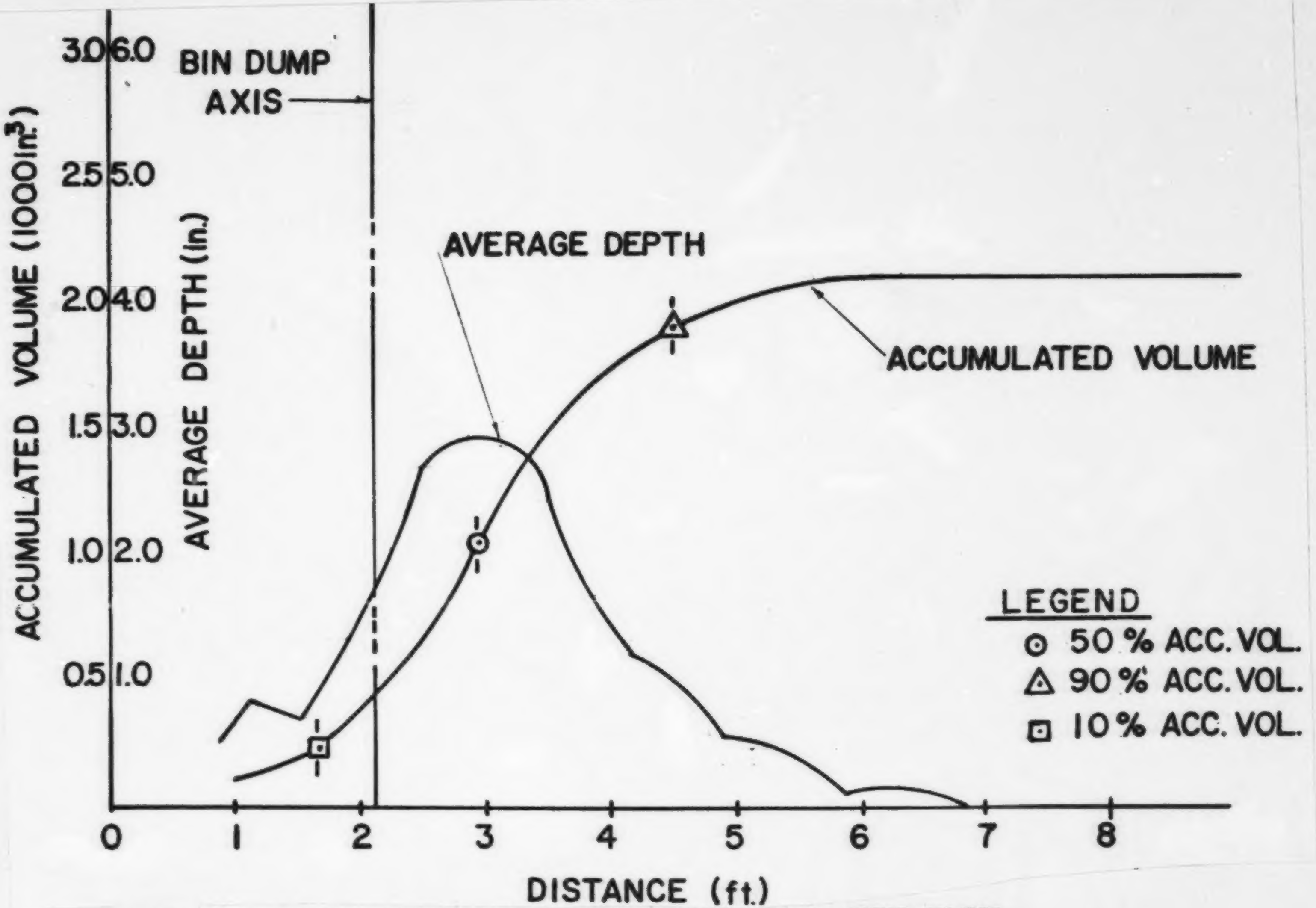


FIG. 23 SOIL DEPOSITION: HANFORD SANDY LOAM: WEIR FLOW

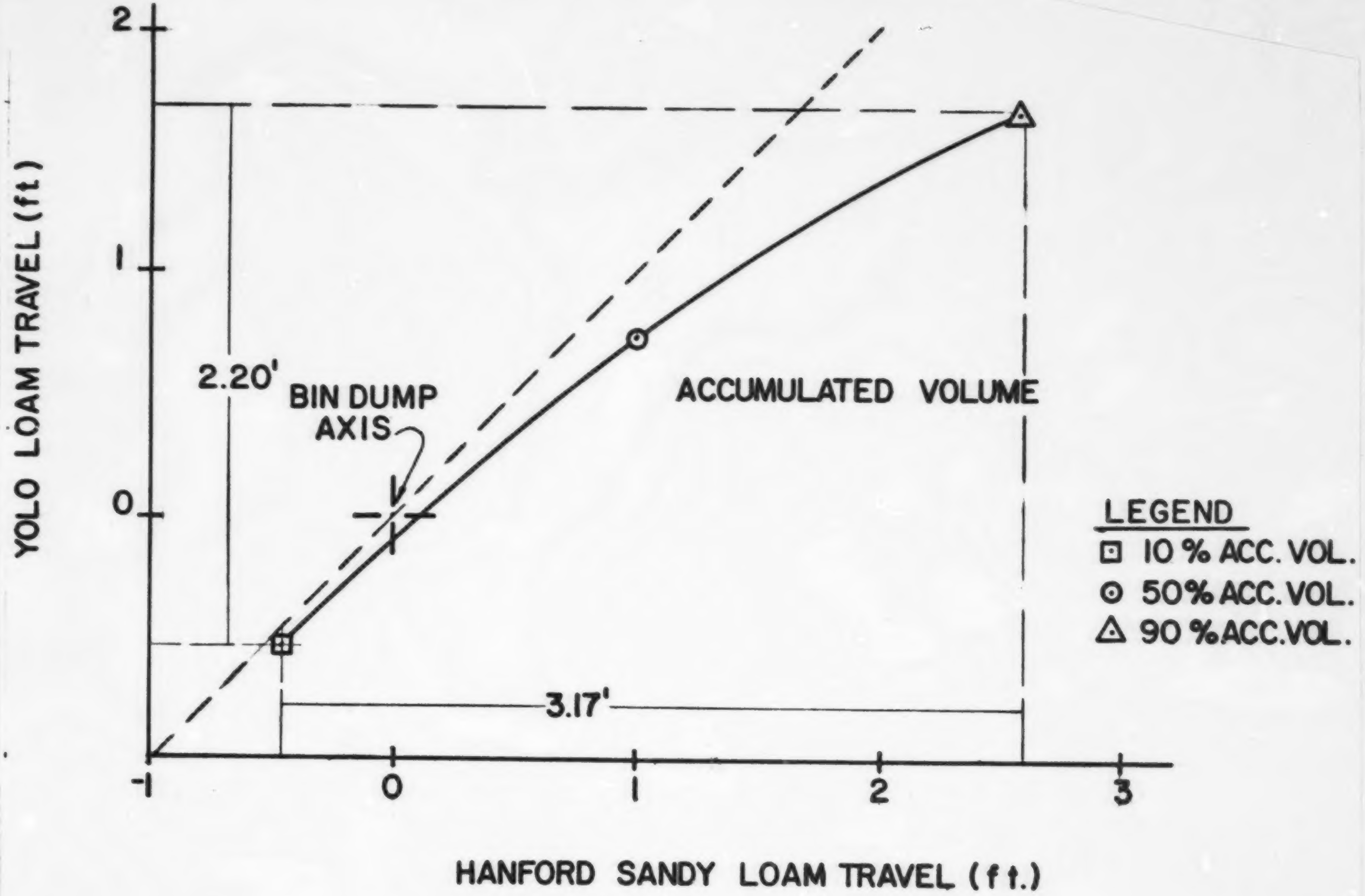


FIG. 24 SOIL TRAVEL DISTANCE COMPARISON

deposition patterns than the recirculated flow. The recirculated flow appeared only to count for subsequent scour and transport of sandy materials such as the Hanford Sandy Loam following deposition. It was concluded, therefore, that the introduction of product from the bins was the dominant force that should be considered in determining the initial soil deposition patterns in bin dump systems.

Preliminary test of the soil collection and transport system were conducted using low scour channel velocities. Low velocities were used in order to minimize the scour channel turbulence generation which might otherwise transport soil particles beyond the hopper. With the low scour channel velocities, soil accumulated in the scour channel and resulted in very poor collection and transport efficiency. Figure 25 shows the soil deposition patterns with the low scour channel velocities indicating the accumulation of soil in the scour channel. Table 5 summarizes the distribution of soil in the collection and transport system under the conditions of low scour velocities. Only approximately 30% of the loaded soil was effectively collected and transported from the bin dump to the solids separation system using the low scour velocities.

Due to the poor results using the low scour velocities, the scour channel design was modified to provide higher scour velocities with the scour jets oriented at a 10 degree angle with respect to the scour channel bottom. This angle provided a means of spreading the scour flow across the base of the scour channel. Velocities were adjusted to provide a minimum three foot per second bottom velocity. Figure 26 shows the soil deposition following a complete run with Hanford Sandy Loam. It should be noted that the scour channel is reasonably free of accumulated soil.

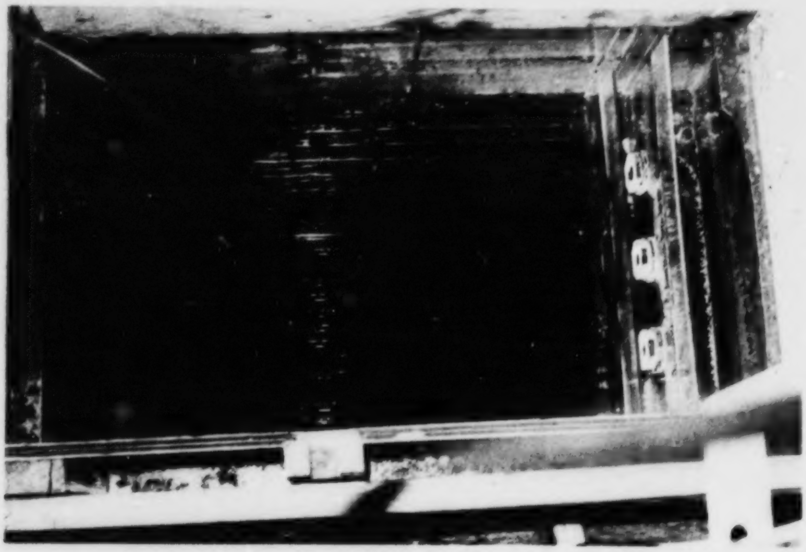
Tests were conducted using high scour velocities with a sub-bottom and an above-bottom scour channel. Based on the data in Table 5, there was no particular advantage in using a sub-bottom scour channel from the standpoint of the over-all system collection and transport efficiency. In both cases, approximately 80% of the loaded soil was effectively collected and transported to the solids separation system.

The pattern of soil deposition obtained by using high scour channel velocities (See Figure 26) showed an accumulation of relatively fine soil particles immediately downstream of the hopper and false bottom. Observation of the flow pattern in the bin dump indicated that this accumulation of material was primarily due to the transport of the soil particles by turbulence generated by the high scour channel velocities. Thus, in spite of the fact that the scour channel and false bottom should have effectively removed 90% of the loaded soil based on conventional bin dump operations, the use of the scour channel with the high scour velocities resulted in a reduction in the overall collection efficiency. Since reduction of the

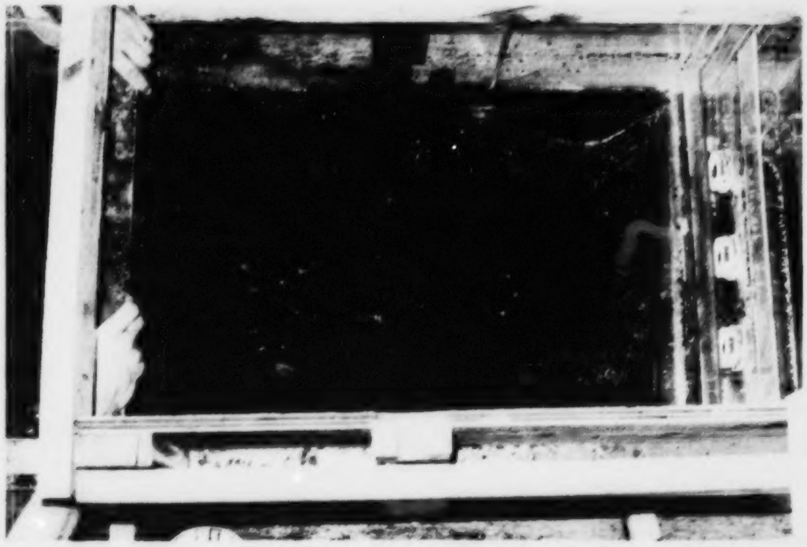
TABLE 4

SUMMARY OF DEPOSITION PATTERNS

SOIL	RECIRCULATED FLOW	DISTANCE FROM BIN DUMP AXIS (FT.)		
		ACCUMULATED VOLUNE (%)		
		10	50	90
Yolo Loam	Jet Flow	-.52	0.84	1.64
	Weir Flow	-.71	0.42	1.54
	Average	-.62	.63	1.59
Hanford Sandy Loam	Jet Flow	-.68	1.11	2.84
	Weir Flow	-.43	0.89	2.37
	Average	-.56	1.00	2.61



WITH FALSE BOTTOM IN PLACE



LEFT: SCOUR CHANNEL RIGHT: HOPPER

FIGURE 25

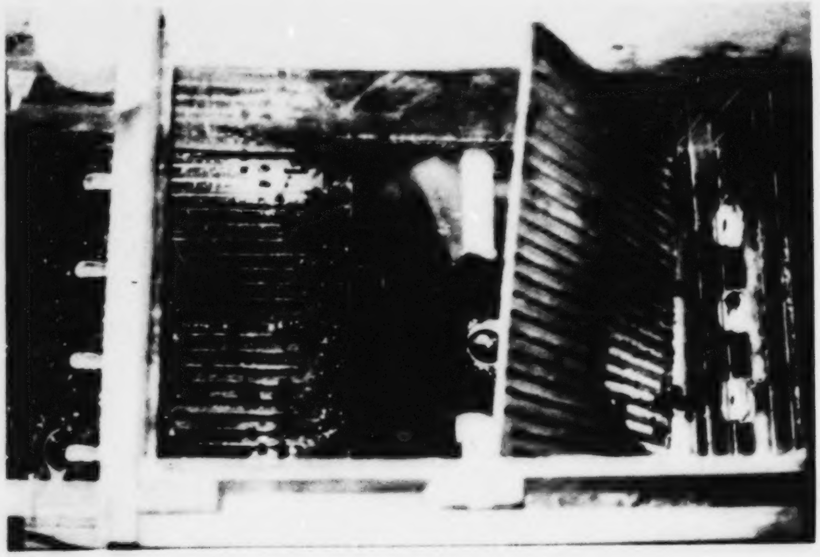
SOIL DEPOSITION WITH LOW SCOUR CHANNEL VELOCITIES

TABLE 5

SUMMARY OF TRANSPORT SYSTEM EFFICIENCIES

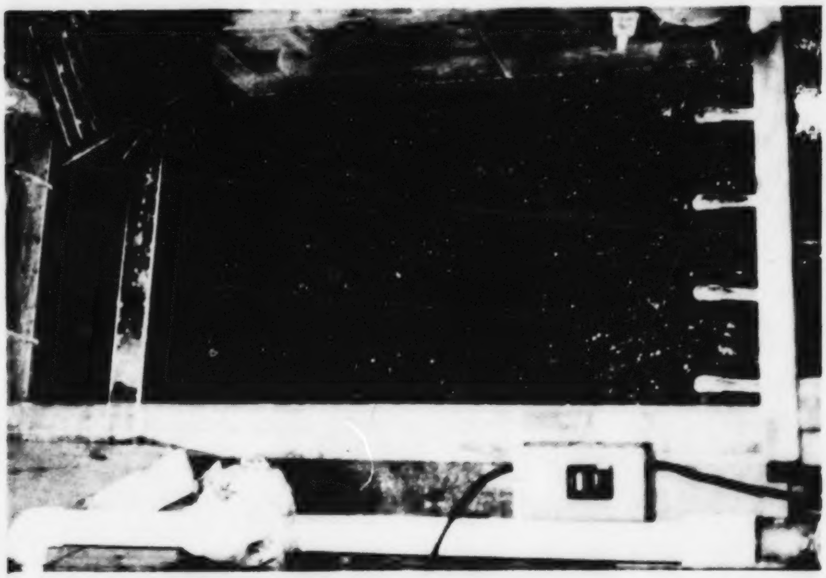
TEST DESCRIPTION	TRANSPORTED SOIL (in^3)	RESIDUAL SOIL (in^3)	TRANSPORT EFFICIENCY (%)
Hanford Sandy Loam - Low Scour Velocities	573	1352[1]	30
Yolo Loam - Low Scour Velocities	752	1798[1]	29
Hanford Sandy Loam - High Scour Velocities with Sub-Bottom Scour Channel	1374	331	81
Hanford Sandy Loam - High Scour Velocities without Sub-Bottom Scour Channel	1647	403	80

1. Averages



FALSE BOTTOM ACCOMULATIONS

FIGURE 26



DEPOSITION DOWNSTREAM OF SOIL REMOVAL SYSTEM

SOIL DEPOSITION WITH HIGH SCOUR CHANNEL VELOCITIES

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scour channel velocities reduce this effect, soil could deposit in the scour channel and offset the advantages gained by reducing turbulence.

Effective soil collection and transport could be achieved through use of a properly sized and located false bottom with a hopper and scouring jets to transport accumulated soil into the hopper. On the basis of the normal bin dump operation soil deposition pattern, the measured efficiency for collection and transport in this system was approximately 90% of that predicted. (See Figure 27)

FULL SCALE SYSTEM

The design criteria for the full scale grit collection and transport system developed on the basis of the model study results are summarized on Table 6. The preliminary design for the grit collection and transport system are shown in Figure 28. This design provided a constant flow to the ejector, with a calibration valve downstream of the ejector transport point to fix the relative amount of pumped secondary flow. A single pump was used to withdraw the ejector pumped flow and any additional flow utilized for product transport. This quantity of water was then transferred to the water recycle system for solids separation. The system should be capable of providing a constant flow from the base of the hopper to the pump intake. Under normal operation the valve on the ejector discharge would be adjusted so that the pump could always pump in excess of the amount of fluid transferred to it by the ejector system. This would provide additional flow for product transport. This additional flow would be returned to the bin dump through the scour channel system or through the make up water point from the thickener overflow. The control system objective would be to balance the additional flow with the thickener overflow quantity.

Figures 29 and 30 show the details for a full scale collection and transport system. Figure 29 shows the flow diagram of the full scale system that was operated at Modesto. Figure 30 is a plan view of the full scale system interfaced with the water recycle system for solids separation.

ANALYSIS OF WATER CONSUMPTION

Water use in a typical tomato processing plant can be categorized as; 1) filling, 2) operation, 3) clean-up. The water used for filling purposes represents that portion of water used to fill up a dump tank, an inside washer, or a distribution flume. The water used for operation purposes represents the portion of water which is continuously utilized during a shift operation, such as bin wash, spray onto trash belt for cleaning purposes, and final rinse of the tomatoes. Clean-up water is that portion of water used both during the operation for cleaning the floor and other facilities, tank washing and flumes and floor washing during the shutdown clean-up.

TABLE 6

DESIGN CRITERIA FOR GRIT COLLECTION AND TRANSPORT

ITEM	DESIGN CRITERIA
1. Bin Dump Product Transport Velocity	10 fpm
2. False Bottom Length	4 ft.
3. Scour Channel Length	3 ft.
4. Total Collector Length	7 ft.
5. False Bottom Clear Space Opening	3/4 in. @ 1¼ in. c.c.
6. Scour Channel Velocity	> 3 fps
7. Ejector Pumped/Motive Flow Ratio	1.0
8. Ejector Motive Flow	250 gpm
9. Soil Collection Hopper	2 ft. depth @ 1:1 side slope

20/92

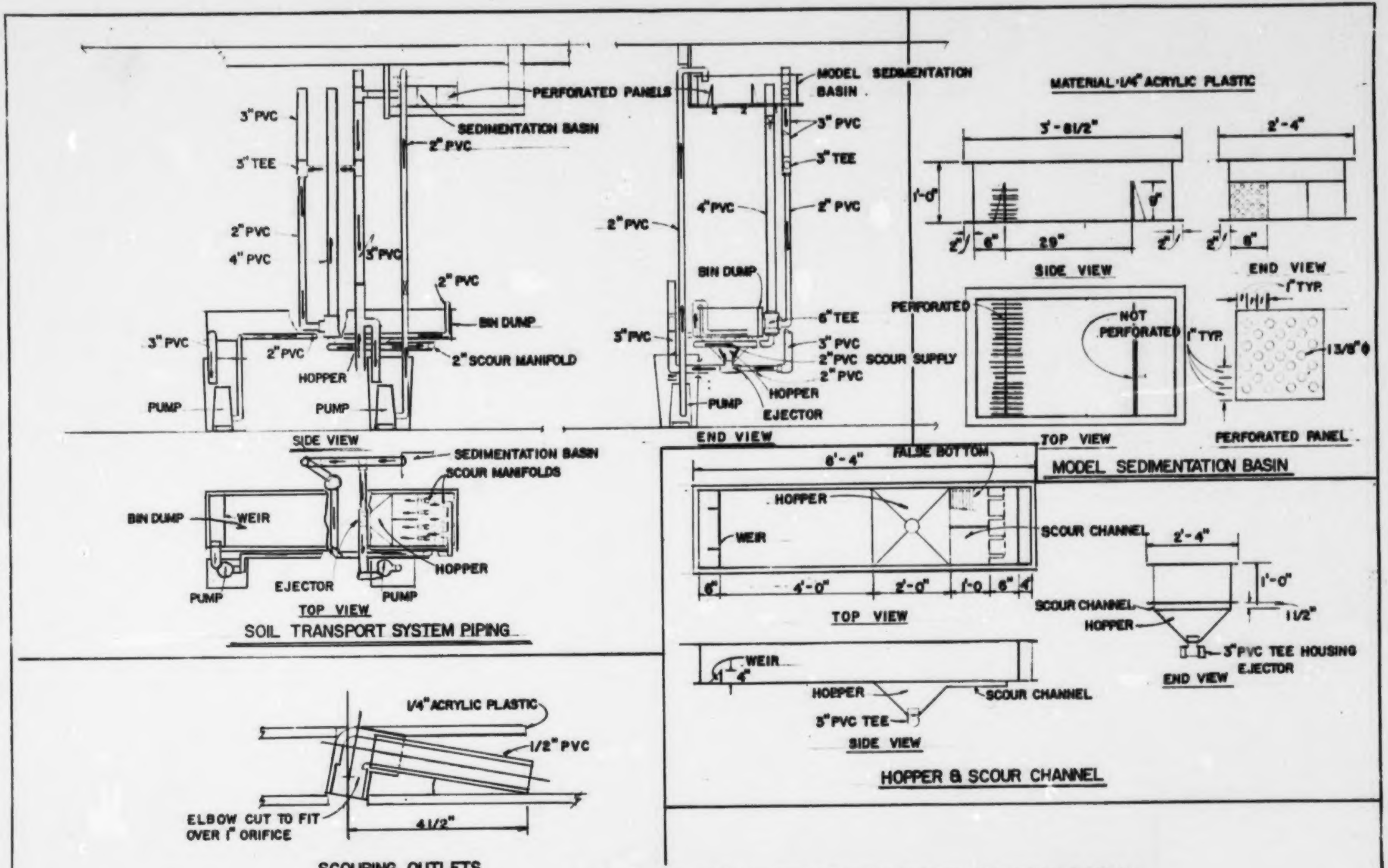
PERFORATED PANELS
SEDIMENTATION BASIN
2" PVC
3" PVC
3" TEE
2" PVC
4" PVC
3" PVC
2" PVC
BIN DUMP
3" PVC
2" PVC
2" SCOUR MANIFOLD
HOPPER
PUMP
PUMP
SIDE VIEW
MODEL SEDIMENTATION BASIN
3" PVC
3" TEE
4" PVC
2" PVC
2" PVC
BIN DUMP
6" TEE
3" PVC
3" PVC
2" PVC SCOUR SUPPLY
2" PVC
HOPPER
PUMP
EJECTOR
END VIEW
SEDIMENTATION BASIN
SCOUR MANIFOLDS
BIN DUMP
WEIR
EJECTOR
HOPPER
PUMP
PUMP
TOP VIEW
SOIL TRANSPORT SYSTEM PIPING
MATERIAL-1/4" ACRYLIC PLASTIC
3'-81/2"
2'-4"
1'-0"
9"
2"
6"
29"
2"
2"
8"
SIDE VIEW
END VIEW
1" TYP.
PERFORATED
NOT PERFORATED
1" TYP.
13/8" ϕ
TOP VIEW
PERFORATED PANEL
MODEL SEDIMENTATION BASIN
6'-4"
FALSE BOTTOM
HOPPER
WEIR
SCOUR CHANNEL
6"
4'-0"
2'-0"
1'-0
6"
4"
TOP VIEW
2'-4"
1'-0"
11/2"
SCOUR CHANNEL
HOPPER
3" PVC TEE HOUSING EJECTOR
END VIEW
WEIR
4"
HOPPER
SCOUR CHANNEL
3" PVC TEE
SIDE VIEW
HOPPER & SCOUR CHANNEL
1/4" ACRYLIC PLASTIC
1/2" PVC
ELBOW CUT TO FIT OVER 1" ORIFICE
41/2"
SCOURING OUTLETS

FIG 27 SOIL COLLECTION & TRANSPORT SYSTEM DESIGN

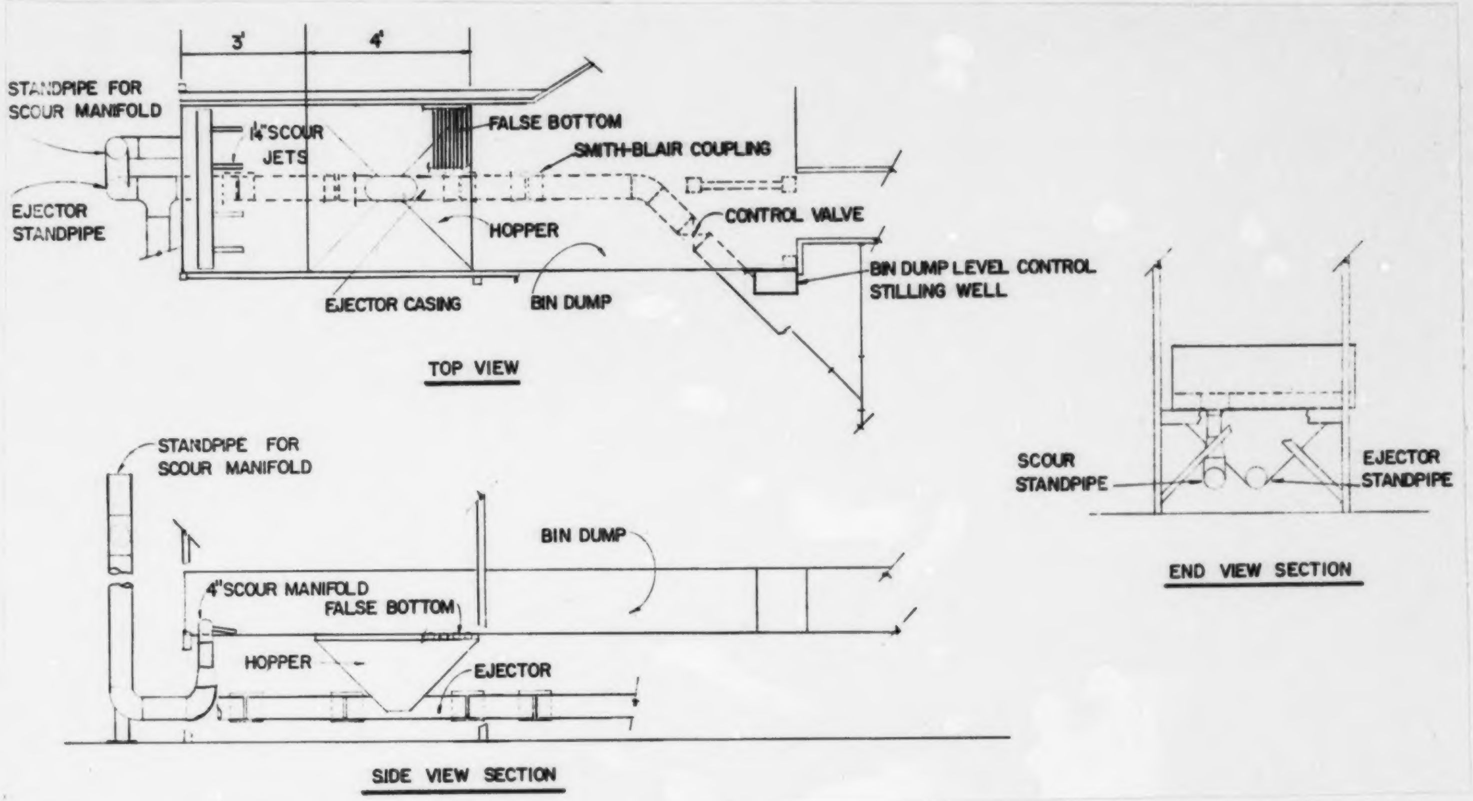
3'
4'
STANDPIPE FOR SCOUR MANIFOLD
1¼" SCOUR JETS
FALSE BOTTOM
SMITH-BLAIR COUPLING
EJECTOR STANDPIPE
CONTROL VALVE
HOPPER
BIN DUMP LEVEL CONTROL STILLING WELL
EJECTOR CASING
BIN DUMP
TOP VIEW
STANDPIPE FOR SCOUR MANIFOLD
BIN DUMP
4" SCOUR MANIFOLD
FALSE BOTTOM
HOPPER
EJECTOR
SIDE VIEW SECTION
SCOUR STANDPIPE
EJECTOR STANDPIPE
END VIEW SECTION

FIG. 28 FULL SCALE GRIT COLLECTOR & TRANSPORT SYSTEM DESIGN

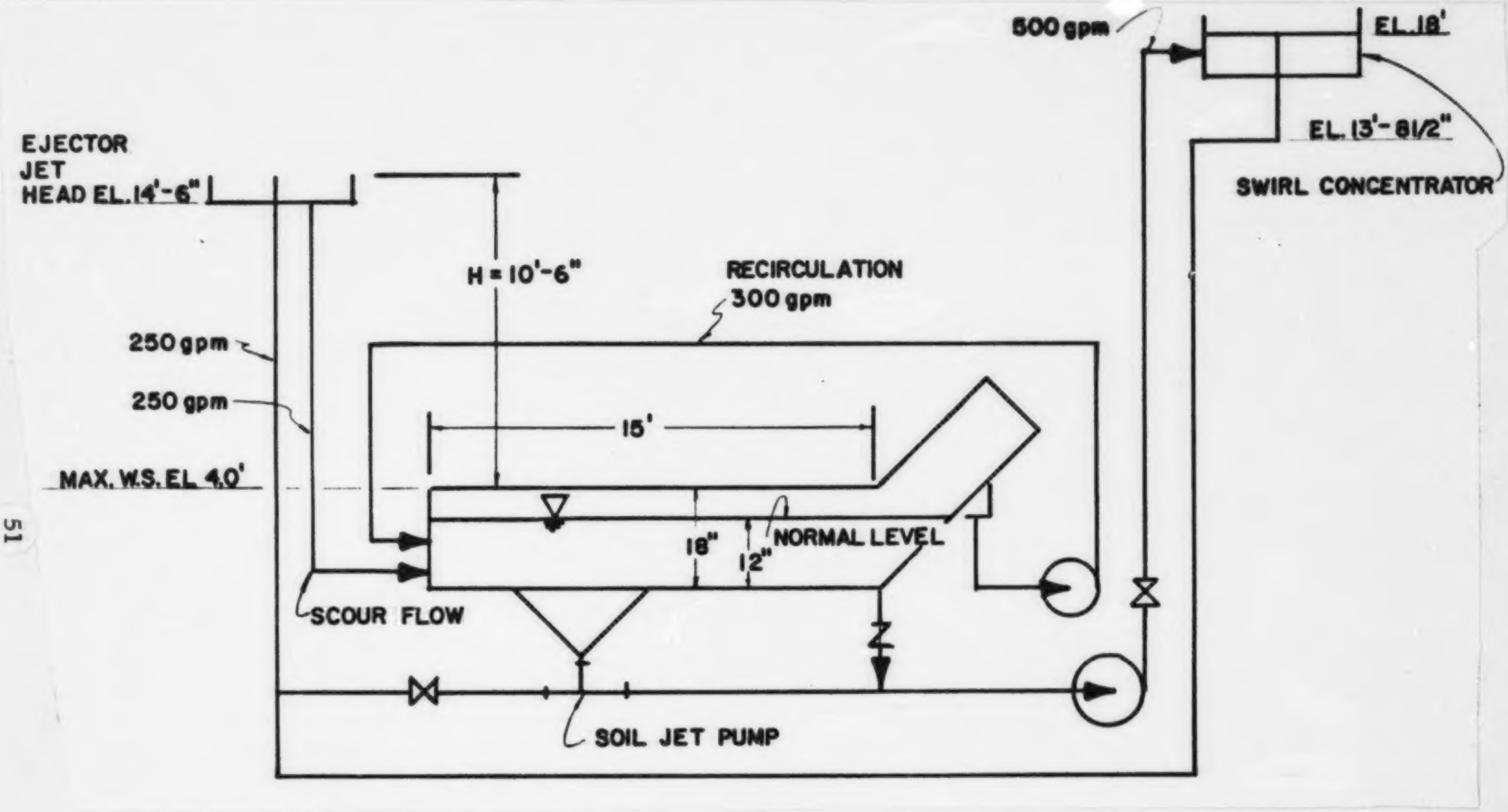
500 gpm
EL. 18'
EL. 13'- 81/2"
SWIRL CONCENTRATOR
EJECTOR
JET
HEAD EL. 14'-6"
H = 10'-6"
RECIRCULATION
300 gpm
250 gpm
250 gpm
15'
MAX. W.S. EL. 4.0'
18"
12"
NORMAL LEVEL
SCOUR FLOW
SOIL JET PUMP

FIG. 29 FULL SCALE SYSTEM FLOW DIAGRAM

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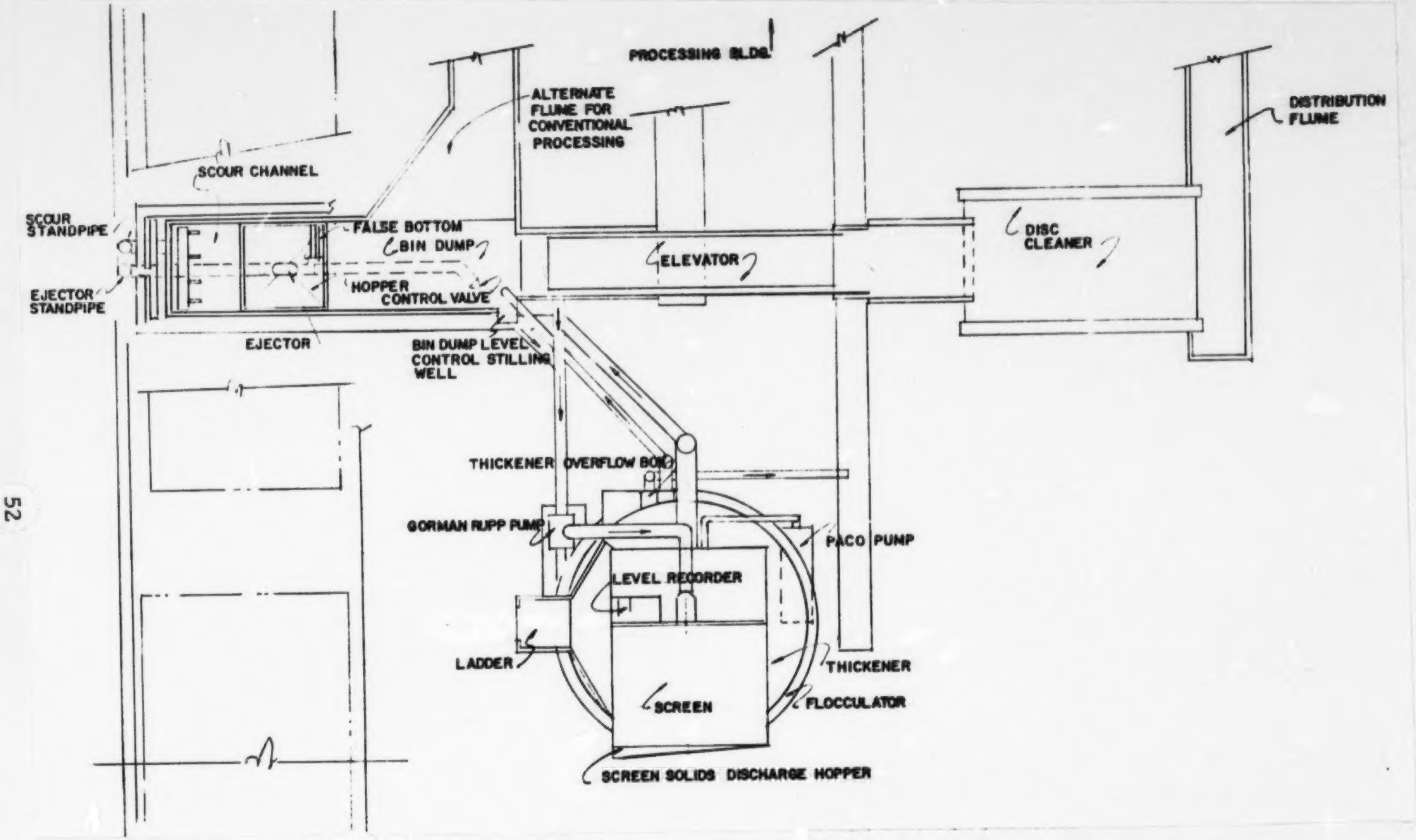
PROCESSING BLDG.
ALTERNATE FLUME FOR CONVENTIONAL PROCESSING
DISTRIBUTION FLUME
SCOUR CHANNEL
SCOUR STANDPIPE
FALSE BOTTOM
BIN DUMP
ELEVATOR
DISC CLEANER
EJECTOR STANDPIPE
HOPPER
CONTROL VALVE
EJECTOR
BIN DUMP LEVEL CONTROL STILLING WELL
THICKENER OVERFLOW BOX
GORMAN RUPP PUMP
PACO PUMP
LEVEL RECORDER
LADDER
THICKENER
SCREEN
FLOCCULATOR
SCREEN SOLIDS DISCHARGE HOPPER

FIG. 30 PLAN VIEW OF FULL SCALE SYSTEM

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Tabulations of the daily water consumptions for various usage are presented in Appendix A.* These tabulations are grouped for four modes of operation and are presented in both operational and clean-up periods. For each water usage the data show the source of the usage. For example, on September 3, 1975, the mode of operation was the conventional washing system. During the second shift operation, water usage was 2,800, 25,800, and 5,600 gallons for filling, operational, and clean-up, respectively. The total water used for the shift was 34,200 gallons. Data also show the total volume of soil solids removed from dump tank during each shift; for example, there was the equivalent of 180 gallons of soil solids which were shoveled out of the dump tank.

A detailed analysis of daily water consumption for various usage is also included in Appendix A. Using the same example of September 3, the total water uses were 34,200 and 41,300 gallons for shift 2 and shift 3 respectively. The total water used was 113,000 gallons after adjusting for missing data.

Shift water usage was 30 and 36 percent for the second and third shifts, respectively. There were no significant variations in water usage among shifts. This was true for most of the data recorded. Water needed for clean-up during the third shift was only 9% of the total water used during the shift. Data are also presented in terms of phase percentage for the total water used during each shift, and phase percentage of the daily total water used. Total unit water usage was 250 gallons per ton of tomatoes processed.

Table 7 summarizes the total water consumption during the whole period of evaluation. In this table, the mode of operation is categorized as conventional washing system; conventional washing with swirl concentrator water recycle; disc cleaner with swirl concentrator water recycle; and disc cleaner with swirl concentrator, water recycle and chemical flocculation. Daily water consumption is presented according to the filling, operation and clean-up purpose. There was no apparent difference in the amount of water used for clean-up by the various modes of operation. Daily total for clean-up purposes was considered to be relatively uniform regardless of the modes of operation. Therefore, in this analysis, the total daily water usage for clean-up purposes was based on the average of the entire period of operation. The average daily water usage for clean-up was 41,500 gallons as indicated in Table 7.

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*Copy can be obtained from EPA, Cincinnati.

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TABLE 7

SUMMARY OF DAILY WATER CONSUMPTION

Mode of Operation	Date (1975)	Tomatoes Processed (ton/day)	Water Used at Various Purposes						Total Water Usage	Total Unit Usage
			Filling Purpose		Operation Purpose		Clean-up Purpose ++			
			(gal/day)	(gal/ton)	(gal/day)	(gal/ton)	(gal/day)	(gal/ton)	(gal/day)	(gal/ton)
Conventional	9/3*	462	7,800	17	91,410	198	41,500	90	140,710	305
	9/4	489	10,490	21	95,420	191		85	147,410	301
	9/5	502	9,660	19	79,550	158		83	130,710	260
	9/6	521	13,860	27	96,190	185		80	151,550	291
	9/8**	398	10,290	26	71,970	181		104	123,760	311
	9/9*	515	12,240	24	53,100	103		81	106,840	207
Conventional with Swirl., No Floc.	9/10	433	10,470	24	67,100	155	41,500	96	119,070	275
	9/11*	291	7,390	25	45,970	158		143	94,860	326
	9/12	560	10,510	19	71,630	128		74	123,640	221
	9/13	494	12,660	26	54,590	111		84	108,750	220
Disc Cleaner with Swirl., No Floc	9/16	597	6,770	11	50,750	85	41,500	70	99,020	166
	9/17	532	7,580	14	57,800	109		78	106,880	201
	9/18	570	6,880	12	46,220	81		73	94,600	166
	9/19	591	6,620	11	39,180	66		70	87,300	148
	9/20	514	5,810	11	38,270	75		81	85,580	167
	9/30	675	5,920	9	53,880	80		61	101,300	150
	10/1	648	6,310	10	46,820	72		64	94,630	146
	10/2	618	11,270	18	50,170	81		67	102,940	167
	10/3	602	5,480	9	31,980	53		69	78,960	131
	10/4	572	6,560	11	53,430	94		73	101,490	177
	10/7	567	6,690	12	24,210	43		73	72,400	128
	10/8	646	8,070	12	38,590	60		64	88,160	136
Disc Cleaner with Swirl., with Floc	9/22**	558	4,050	7	52,800	95	41,500	74	98,350	176
	9/23	634	6,160	10	47,410	75		65	95,070	150
	9/24	621	6,970	11	47,440	77		67	95,910	154
	9/25	625	11,410	18	58,190	93		66	111,100	178
	9/26	620	6,810	11	59,010	95		67	107,320	173
	9/27	531	7,060	13	54,350	102		78	102,910	194
	10/9	620+	7,270	12	42,690	69		67	91,460	148
	10/10	620+	4,140	7	44,650	72		67	90,290	146
	10/11	620+	4,050	7	53,070	86		67	98,620	159

* Date available for two of the three shifts
** Date available for one of the three shifts
+ Estimated
++ Averaged value

1. Average Water Usage at Various Modes of Operation

Total and unit water consumption rates have been averaged and summarized in Table 8. Average, for 6 days data, showed the amount of tomatoes processed using the conventional washing system was 481 ton/day; the total water usage was 133,500 gallons/day; and, the average unit water consumption rate was 280 gallons/ton of tomatoes processed. During the second mode of operation of conventional with water recycle (4 consecutive days of operation), the average amount of tomatoes processed was 445 tons/day; the average water consumption was 109,100 gallons/day; and the average unit water consumption rate was 145 gallons/ton of tomatoes processed. For operation of disc cleaner with water recycle, the average (12 days operation) amount of tomatoes processed was 594 tons/day; the average water consumption was 92,800 gallons;day; and, the average unit water consumption rate was 156 gallons/ton of tomatoes processed. For operation of disc cleaner with water recycle and chemical flocculation, the average (5 days operation) amount of tomatoes processed was 605 tons/day; the average water consumption was 99,000 gallons/day; and, the average unit water consumption rate was 164 gallons/ton of tomatoes processed.

Observations and conclusions based on data presented here are:

1. The daily average tonnage of tomatoes processed increased substantially when water recycling measures were employed. For example, an increase of 25% in the tonnage of tomatoes processed was realized when disc cleaner with water recycle and chemical flocculation was applied as opposed to applying conventional washing operation. The increases in the daily tonnage of tomatoes processed may be due primarily to the increase in the soil solids removal efficiency from the dump tank. There was no significant accumulation of solids in the dump tank to hinder the tomato washing operation. No incident of temporary shutdown of the operation was encountered during the modes of operation with water recycle. It appeared that the tomatoes could be washed and processed at a faster rate when no significant amount of solids accumulated in the dump tank.

2. A decrease of 26% in the average total daily water usage was realized when disc cleaner with water recycling and chemical flocculation was applied as opposed to applying conventional washing operation. Decreases in water usage were noted for both filling and operational purposes.

3. An important result was the significant decrease in the average unit water consumption rate (gallons of water used per ton of

tomatoes processed) when water was recycled.

2. Average Percentage of Water Consumption

Table 8 presents the average percentage of water consumption for various water usages. These data indicate that the majority of daily water usage was for operational purposes (45%-61%) and followed by clean-up (31%-44%) and filling (6%-8%) purposes. For the same usage purpose there were no significant variations in the percentage of total daily usage at various modes of operation. For example, approximately 7% of daily water usage was for filling purposes, approximately 55% for operational purposes, and approximately 39% for clean-up purposes.

3. Hydraulic Balance at Recycling Component

Average flows to the swirl concentrator during each of the three shifts and for each of the three operational modes investigated are shown in Table 9. Flows to the swirl concentrator equalled about 1000,000 gallons/shift for all three operational modes. For all operational modes the flow to the swirl concentrator was consistently lower during the second shift than durint the first and third shifts. There is no apparent explanation for this result.

For the operation with water conservation and reuse, the design was such that the only source of water discharged to the sewer was the thickener supernatant. The purpose of this was to discharge only clarified thickener wastewater. During each shift the average flow from the thickener overflow to the sewer was equivalent to the total make-up water. Water from the thickener overflow to the sewer equalled about 15,000-20,000 gallons/shift for all three operational modes. The sewered flow was about 40-65% of the total shift flow.

Analysis of Mass Balance Performance

Soil solids removed by the water recycle and reuse system were also studied. Table 10 gives the total solids concentrations for various flow schemes.

For water in the dump tank, inside washer, and distribution flume, there was no significant difference in the solids concentration at various modes of operation. However, there was significant reduction in solids that overflow to the sewer. For example, 8,000 mg/l of solids overflowed to the sewer using the conventional washing system, and 4,000 to 5,000 mg/l overflowed when recycling and reuse measures were used. During conventional washing, overflow to the sewer was from the Tank 1. This formed an internal water recycling loop with the dump tank. Water samples

TABLE 8

SUMMARY OF AVERAGE WATER CONSUMPTION AT VARIOUS MODES OF OPERATION

Mode of Operation	Average Tomato Processed (ton/day)	Average Water Consumption (gal/day)				Average Unit Water Consumption Rate (gal/ton)
		Filling Purpose	Operational Purpose	Clean-up * Purpose	Total	
Conventional	481	10,700	81,300	41,500	133,500	278
Conventional w/Swirl - w/o Floc.	445	7,800	59,800	41,500	109,100	245
Disc Cleaner w/Swirl - w/o Floc.	594	7,000	44,300	41,500	92,800	156
Disc Cleaner w/Swirl - w/Floc.	605	6,400	51,100	41,500	99,000	164

* Averaged Value

TABLE 9

AVERAGE TOTAL FLOW TO SWIRL CONCENTRATOR AND OVERFLOW TO SEWER DURING EACH SHIFT

Mode of Operation	Average Total Flow to Swirl Concentrator						Average Total Overflow to Sewer					
	Shift 1		Shift 2		Shift 3		Shift 1		Shift 2		Shift 3	
	Quant. (gal)	% of Shift Total Flow	Quant. (gal)	% of Shift Total Flow	Quant. (gal)	% of Shift Total Flow	Quant. (gal)	% of Shift Total Flow	Quant. (gal)	% of Shift Total Flow	Quant. (gal)	% of Shift Total Flow
Conventional w/Swirl-w/o Floc	118,600	385	90,200	260	100,700	325	21,500	65	16,900	49	21,400	65
Disc Cleaner w/Swirl-w/o Floc	124,600	373	105,500	286	102,400	308	15,600	42	17,200	46	18,000	49
Disc Cleaner w/Swirl-w/Floc	104,800	284	88,300	246	106,800	287	17,800	47	16,500	45	17,600	47

TABLE 10

REPRESENTATIVE TOTAL SOLID CONCENTRATIONS AT VARIOUS FLOW SCHEMES

Mode of Operation	Dump Tank (mg/l)	Inside Washer (mg/l)	Distribution Flume (mg/l)	From Disc Cleaner (mg/l)	Overflow to Sewer (mg/l)	Into Swirl Concentrator (mg/l)	Overflow From Swirl Concentrator (mg/l)	Solid From Dump Tank (%)	Solid From Thickener (%)
Conventional	8,000	750	350	--	8,000	--	--	60	--
Conventional with Recycling	4,000	1,000	300	--	4,000	8,000	7,000	64	30
Disc Cleaner with Recycling	--	--	400	2,000	4,000	6,000	5,000	64	32
Disc Cleaner with Recycling and Chemical	--	--	500	2,500	5,000	7,000	6,000	60	30

representing dump tank water were collected from Tank-1. Therefore, the solid concentration of 8,000 mg/l was a combination of both water from dump tank and overflow to the sewer.

Solid concentrations of the influent to the swirl concentrator ranged from approximately 6,000 to 8,000 mg/l for all modes of operation. Solids to the swirl concentrator represented the total solids, which were collected from the false bottom and transported by an ejector and pump. It was noted that the solids separated from the screen were primarily tomato seeds and other debris. These were collected by a gondola. Approximately 30 cubic feet of solids were collected daily from the screen. Since these solids were primarily tomato seeds generated from broken tomatoes, this portion of solids was not measured as part of incoming soil to the plant.

Differences between the solid concentrations of overflow from the swirl concentrator and influent to the swirl concentrator were only 1,000 mg/l. This was true for all modes of operation. This result indicated that the majority of the solids were not readily settleable and were not separated by the swirl concentrator. In addition to other design parameters, the solids removal efficiency of the swirl concentrator was apparently affected by the particle size distribution of the soil. Hence, the type of soil, the moisture content of the soil when the tomatoes were harvested and the method of tomato harvesting all affected the amount of soil solids carried to the processing plant. These "unaccountable" factors might explain variations in some of the results obtained during the study.

Jar tests were conducted to determine the optimum coagulant concentration during the disc cleaner operation with water recycle and chemical flocculation. Due to the daily variations in the soil characteristics, jar tests conducted over a period of several days indicated that the desiged coagulant concentrations ranged from 7 to 15 mg/l. An evaluation was made of the various degrees of clarification with various chemical dosage rates. Chemical dosages applied during this mode of operation are shown in Table 11.

All the ISCO water samplers were out of order, and, consequently, the grab sampling technique was used during this period. Due to the variation in solids levels to the plant, it was difficult to collect representative samples by grab sampling techniques. However, evaluations were conducted in terms of the average soil solids loadings among various modes of operation.

Average Soil Solid Loadings

Table 12 presents the average soil solids loadings and unit solid loading rates for various modes of operation. Because the quantity of

TABLE 11

CHEMICAL DOSAGES APPLIED DURING THE OPERATION OF DISC CLEANER WITH RECYCLING AND CHEMICAL FLOCCULATION

Date	Chemical Dosage (mg/l) (Cat-Floc T, Calgon Product)
9/22/75	17.5
9/23/75	26.0
9/24/75	17.0
9/25/75	11.0
9/26/75	6.5
9/27/75	7.0
10/9/75	7.0
10/10/75	12.5
10/11/75	10.0

tomatoes processed increased in the washing system with water conservation and reuse measures, it was more meaningful to present the soil solids loadings and various distributions in terms of both lbs/day and lbs per ton of tomatoes processed. As shown in the second column of Table 12, approximately 2,800 lbs/day of soil solids was removed from the dump tank. This represent a unit soil solids rate of 5.7 lbs/ton of tomatoes processed. As expected, a significant decrease in solids removal from the dump tank was noted as the water conservation and reuse measures were implemented. For example, there were only 940, 680, and 860 lbs/day of soil solids removed from the dump tank for conventional washing with water recycle, and disc cleaner with and without chemical flocculation, respectively. The unit soil solids removed from dump tank were 2.1, 1.2, and 1.4 lbs/ton for those three modes of operation, respectively.

Several important observations and conclusions can be drawn from the data presented on Table 12:

1. Plant capacity for tomato processing increased as water conservation and reuse measures were employed.

2. Soil solids removed from the dump tank per unit weight of tomatoes processed decreased significantly when water conservation and water reuse measures were used.

3. Soil solids loads to sewer per tonnage of tomatoes processed decreased when water conservation and reuse measures were implemented.

4. Soil solids removed from the thickener per unit weight ot tomatoes processed increased when water conservation and reuse measures were used.

5. The estimated soil solids per unit of tomatoes processed ranged from 10 to 18 lbs/ton, with an average of 13 lbs/ton of tomatoes processed.

Soil Solids Loading

An analysis of the soil solids distribution at various operational modes is presented on Table 12. With a conventional washing system, 31% of the soil was removed from the dump tank, and the remaining 69% was discharged into the sewer. The percentage of soil solids discharged into the sewer decreased as water conservation and reuse measures were implemented. For example, for conventional washing with water recycling, 20% of the soil solids was removed from the dump tank, 49% was discharged into the sewer, and 31% was removed by the thickener. For both

TABLE 12

AVERAGE TOTAL SOIL SOLIDS LOADINGS AT VARIOUS OPERATIONAL MODES

Mode of Operation	Total Tomato Processed (tons/day)	Soil Solids Removal From Dump Tank		Soil Solids Lost to Sewer		Soil Solids Removed From the Thickener		Total Soil Solids to the Plant (lbs/day)	Soil Per Unit of Tomato (lbs/ton)
		(lbs/day)	(lbs/ton)	(lbs/day)	(lbs/ton)	(lbs/day)	(lbs/ton)		
Conventional	481	2757	5.7	6029	12.5	--	--	8786	18
Conventional w/Swirl - w/o Floc.	445	941	2.1	2332	5.2	1453	3.3	4726	11
Disc Cleaner w/Swirl - w/o Floc.	594	684	1.2	1609	2.7	3353	5.7	5646	10
Disc Cleaner w/Swirl - w/Floc.	605	856	1.4	2920	4.8	4568	7.6	8344	14

systems, with the disc cleaner, the percentage of soil solids removed by the thickener increased significantly, at the same time the percentage of soil solids removed from the dump tank and discharged to the sewer decreased substantially. One significant point which should be noted is that the unit rate of soil solids removed from the dump tank was significantly less when a washing system with conservation and water reuse was applied. This indicated that the majority of soil solids was effectively removed and transported to the swirl concentrator for further solids separation. Consequently, only a marginal portion of soil solids was left in the dump tank and removed at the end of each shift.

The fourth and fifth columns of Table 12 present the portion of soil solids lost to the sewer during the operation. Again, it is more meaningful to compare the data in terms of unit soil solids per ton of tomatoes processed. There were 12.5 lbs of soil solids per ton of tomatoes lost to the sewer under conventional washing, whereas 5.2, 2.7 and 4.8 lbs of soil solids per ton were lost to the sewer in systems with water conservation and reuse measures. The sixth and seventh columns of Table 12 present the portion of soil solids removed from the thickener. An average of 3.3, 5.7, and 7.6 lbs/ton of tomatoes processed was removed from the thickener for the conventional washing system with water recycle, disc cleaner with recycle, and disc cleaner with recycle and chemical flocculation, respectively. These data indicate that the unit weight of soil solids removed from the thickener increased as more sophisticated removal measures such as chemical flocculation were implemented. The last column in Table 12 presents the average soil solids loading per unit of tomatoes processed. There were 18, 11, 10, and 14 lbs/ton of tomatoes processed for conventional washing, conventional with recycle, disc cleaner with recycle, and disc cleaner with recycle and with chemical flocculation, respectively.

VACUUM BELT DEWATERING

Data monitored included vacuum belt speed, feed sludge and sludge cake on the belt, sludge cake and filtrate production rate, total solids concentrations of the feeding sludge, and chemical coagulant dosage. Results from this evaluation were interpreted in terms of sludge solids loading rate, cake solids production rate, dewatering efficiency, drying factor, sludge volume reduction efficiency and solids recovery efficiency.

Table 13 presents data for tomato mud dewatering using vacuum belt dewatering without chemical coagulation during the clarification-thickening stage. Belt speeds ranged from 1.3 to 3.6 ft/min. The feed sludge thicknesses ranged from 3/16 to 5/8 inches with an average of 7/16 inches and the sludge cake thicknesses ranged from 1/8 to 1/2 inches with an average thickness of $\frac{1}{4}$ inches. Sludge loading rates ranged from 3.1 to 21.3 gph/ft^2 with an average of 13 gph/ft^2 and sludge cake production ranged from

2.3 to 17.0 gph/ft^2 with an average of 8.6 gph/ft^2. The total solids concentrations for the feed sludge, sludge cake, and filtrate ranged from 12.0 to 45.9, 18.4 to 59.3, and 1.1 to 8.0 percent by weight, respectively. The average total solids concentrations for the feed sludge, sludge cake, and filtrate were 26.4, 39.7, and 2.2 percent by weight, respectively. Filtrate production rates ranged from 0.8 to 8.5 gph/ft^2 with an average of 4.4 gph/ft^2.

Sludge loading rates and sludge cake production rates were estimated from the measured feed sludge thickness and belt speed. Filtrate production rates were estimated from the rates of filtrate collected.

On September 15 and 22, 1976, the vacuum belt dewatering unit evaluated sludge produced by chemical coagulation. The data are presented on Table 14. Comparing this data with that of no chemical coagulation on Table 13, the following observations were made:

1. A slight increase in the thickness of feed sludge and cake was noted with chemical coagulation at the clarification-thickening stage;

2. An increase in the sludge loading rate and sludge cake production rate were noted with chemical coagulation; and

3. A significant increase in the total solids concentrations for the sludge feed and cake was noted with chemical coagulation.

Parameters used in evaluating the sludge dewatering unit included sludge solids loading rate, cake solids production rate, dewatering efficiency, drying factor, sludge volume reduction efficiency, and solids recovery efficiency.

Sludge solids loading rates were estimated by adding the sum of the rate of solids collected in the filtrate and solids in the cake. The former was estimated from the filtrate production rates and the solids concentrations of the filtrate. Similarly, the rates of solids production in the cake were estimated from the sludge cake production rates and the solids concentrations of the cake.

Sludge dewatering efficiency was the efficiency of removing water from the sludge. This parameter was defined as:

$$\text{dewatering efficiency} = \frac{\text{filtrate water out}}{\text{filtrate water out} + \text{cake water out}} \times 100$$

The higher the dewatering efficiency, the more water was removed from the incoming sludge.

Drying factor reflected the increase in solids of the cake as opposed to sludge prior to dewatering. This parameter was defined as the ratio of the solids concentration of the cake to that of its sludge. The higher the drying factor, the higher the cake solids concentration in relationship to the solids concentration in the incoming sludge.

The sludge volume reduction efficiency =

$$= 1 - \frac{\text{Cake volume prod. rate}}{\text{Cake volume prod. rate} + \text{filtrate prod. rate}} \times 100$$

The higher the sludge volume reduction, the smaller the sludge cake volume that must be disposed.

Solids recovery efficiency was defined as:

$$\frac{\text{Cake solids}}{\text{Cake solids} + \text{filtrate solids}} \times 100$$

The higher the solids recovery efficiency, the more efficient was the capture of the solids.

Table 15 presents the results of tomato mud dewatering with the vacuum belt unit without chemical addition. Sludge solids loading rates ranged from 9.8 to 117.3 lbs/hr/ft^2 with an average of 38.9 lbs/hr/ft^2 and cake solids production rates ranged from 8.9 to 116.8 lbs/hr/ft^2 with an average of 38.3 lbs/hr/ft^2. Dewatering efficiencies ranged from 17 to 70 percent with an average of 37 percent; drying factors ranged from 1.21 to 1.89 with an average of 1.53; sludge volume reduction efficiencies ranged from 15 to 49 percent with an average of 30 percent and solids recovery efficiencies ranged from 91 to 99 percent with an average of 97 percent.

The effect of chemical coagulation/flocculation on the sludge dewatering process was investigated during six runs on 9/15/76 and 9/22/76 using

TABLE 13
RESULTS OF TOMATO MUD DEWATERING WITH VACUUM BELT UNIT
(Without Chemical Coagulation at Clarification-Thickening Stage)

Date	Time	Belt Speed (ft/min)	Mud Thickness (in)		Sludge Loading Rate (gph/ft^2)	Cake Production Rate (gph/ft^2)	Total Solids Conc. (%)			Filtrate Production Rate (gph/ft^2)
			Feed	Cake			Feed	Cake	Filtrate	
9/9/76	4:20p	3.6	4/16	2/16	8.6	4.3	25.7	46.9	1.3	2.9
9/9/76	5:00p	2.2	3/16	2/16	3.9	2.6	29.5	42.5	1.1	4.8
9/9/76	6:30p	1.3	4/16	3/16	3.1	2.3	25.9	36.0	2.0	5.2
9/10/76	2:15p	3.6	4/16	2/16	8.6	4.3	32.8	45.7	1.3	2.0
9/10/76	5:10p	3.6	4/16	2/16	8.2	4.2	16.3	28.3	1.9	4.0
9/10/76	6:05p	3.6	9/16	6/16	18.9	12.6	14.5	25.8	1.6	4.2
9/10/76	10:00p	3.6	8/16	4/16	16.8	8.4	29.9	50.0	1.7	2.3
9/10/76	11:20p	3.6	5/16	3/16	10.7	6.4	16.1	26.0	1.8	3.8
9/11/76	4:30a	3.6	6/16	4/16	12.8	8.5	12.0	18.5	3.1	4.0
9/11/76	10:00a	3.6	7/16	4/16	14.9	8.5	20.5	38.0	1.2*	4.0
9/11/76	4:10p	3.6	10/16	8/16	21.3	17.0	30.1	38.6	1.4	3.8
9/11/76	5:05p	3.6	8/16	4/16	17.0	8.5	20.2	34.6	1.7	2.9
9/12/76	1:10a	3.6	9/16	6/16	19.2	12.8	20.4	32.0	3.9	4.6
9/13/76	12:30p	3.6	6/16	4/16	12.8	8.5	38.2	54.4	1.2*	4.6
9/13/76	4:10p	3.6	8/16	4/16	17.0	8.5	31.4	43.1	1.9	2.7
9/13/76	9:30p	3.6	8/16	6/16	17.1	12.8	24.9	33.9	1.6	2.9
9/14/76	1:00a	3.6	8/16	7/16	17.0	14.9	28.8	36.7	1.2	2.6
9/14/76	2:00a	3.6	6/16	4/16	12.8	8.5	27.2	37.2	1.2	3.5
9/14/76	10:00a	3.6	8/16	7/16	17.0	14.9	31.3	59.3	1.8	3.0
9/23/76	12:00a	1.3	8/16	6/16	6.1	4.6	45.9	55.6	8.0	2.5
9/23/76	5:10a	2.2	7/16	5/16	9.1	6.5	33.4	49.5	5.5	5.0
Average			7/16	4/16	13.0	8.6	26.4	39.7	2.2	3.6
Range		(1.3-3.6)	(3/16-10/16)	(3/16-8/16)	(3.1-21.3)	(2.3-17.0)	(12.0-38.2)	(18.5-59.3)	(1.1-8.0)	(2.0-5.2)

*estimated value

TABLE 14

RESULTS OF TOMATO MUD DEWATERING WITH VACUUM BELT UNIT

(With Chemical Addition)

Date	Time	Belt Speed (ft/min)	Mud Thickness (in)		Sludge Loading Rate (gph/ft^2)	Cake Production Rate (gph/ft^2)	Total Solids Conc. (%)			Filtrate Production Rate (gph/ft^2)	Calcon Cat-Floc Concentrate (mg/l)
			Feed	Cake			Feed	Cake	Filtrate		
9/15/76	1:40a	3.6	9/16	7/16	19.2	14.9	41.3	56.2	3.0	4.3	15
	8:40a	3.6	7/16	5/16	16.9	12.1	35.8	55.7	1.5	4.8	15
	4:00p	3.6	6/16	5/16	14.5	12.1	43.6	58.6	2.5	2.4	15
9/22/76	5:00p	3.6	9/16	5/16	19.2	12.1	38.2	58.2	2.8	7.1	20
	6:15p	2.2	8/16	4/16	10.4	5.2	44.7	56.9	5.1	5.2	20
	8:00p	1.3	8/16	6/16	6.1	4.6	39.6	57.6	4.5	1.5	20
Average			8/16	5/16	14.4	10.2	40.5	57.2	3.2	4.2	17.5

TABLE 15

PERFORMANCE EVALUATION OF TOMATO MUD DEWATERING WITH VACUUM BELT UNIT

(Without Chemical Addition)

Date	Time	Sludge Solids Loading Rate (lb/hr/ft^2)	Cake Solids Production Rate (lb/hr/ft^2)	Dewatering Efficiency (%)	Drying Factor	Sludge Volume Reduction (%)	Solids Recovery (%)
9/9/76	4:20p	24.0	23.7	47	1.82	40	99
9/9/76	4:00p	12.9	12.5	70	1.44	35	97
9/9/76	6:30p	9.8	8.9	70	1.39	31	91
9/10/76	2:15p	23.1	22.9	38	1.39	32	99
9/10/76	5:10p	12.6	12.0	52	1.74	49	95
9/10/76	6:05p	32.9	32.3	27	1.78	25	98
9/10/76	10:00p	51.2	50.9	27	1.67	21	99
9/10/76	11:20p	17.2	16.6	40	1.61	37	97
9/11/76	4:30a	15.8	14.8	33	1.54	32	93
9/11/76	10:00a	35.7	35.3	36	1.85	32	99
9/11/76	4:10p	72.4	72.0	20	1.28	18	99
9/11/76	5:05p	31.7	31.3	29	1.71	25	99
9/12/76	1:10a	44.2	42.7	29	1.57	26	97

TABLE 15 (CONT'D)

Date	Time	Sludge Solids Loading Rate (lb/hr/ft^2)	Cake Solids Production Rate (lb/hr/ft^2)	Dewatering Efficiency (%)	Drying Factor	Sludge Volume Reduction (%)	Solids Recovery (%)
9/13/76	12:30p	58.8	58.3	44	1.42	35	99
9/13/76	4:10p	42.0	41.6	29	1.37	26	99
9/13/76	9:30p	46.3	45.9	27	1.36	18	99
9/14/76	1:00a	59.4	59.1	17	1.27	15	99
9/14/76	2:00a	34.7	34.3	36	1.37	29	99
9/14/76	10:00a	117.3	116.8	17	1.89	17	99
9/23/76	12:00p	34.3	32.6	44	1.21	35	95
9/23/76	5:10a	41.1	38.8	50	1.48	43	94
Average		38.9	38.3	37	1.53	30	97
Range		(9.8- 117.3)	(8.9- 116.8)	(17- 70)	(1.21- 1.89)	(17- 49)	(91- 99)

TABLE 16

PERFORMANCE EVALUATION OF TOMATO MUD DEWATERING WITH VACUUM BELT UNIT

(With Chemical Coagulation at Clarification-Thickening Stage)

Date	Time	Sludge Solids Loading Rate (lb/hr/ft^2)	Cake Solids Production Rate (lb/hr/ft^2)	Dewatering Efficiency (%)	Drying Factor	Sludge Volume Reduction (%)	Solids Recovery (%)
9/15/76	1:40a	108.4	107.4	28	1.36	21	99
9/15/76	8:40a	86.5	86.1	26	1.56	20	99
9/15/76	4:00p	93.6	93.1	25	1:34	18	99
9/22/76	5:00p	92.9	92.1	31	1.52	22	99
9/22/76	6:15p	40.5	38.2	62	1.27	51	94
9/22/76	8:00p	35.4	34.5	44	1.45	35	97
Average		76.2	75.2	36	1.42	28	98

Calgon Cat-Floc. The chemical dosage rate during the three runs on 9/15/76 was 15 mg/l; the dosage rate during the other three runs on 9/22/76 was 20 mg/l. These results are presented on Table 16. Sludge solids loading rates ranged from 35.4 to 108.4 lbs/hr/ft^2 having an average of 76.2 lbs/hr/ft^2. Cake solids production rates ranged from 34.5 to 107.4 lgs/hr/ft^2, having an average of 75.2 lgs/hr/ft^2; dewatering efficiencies ranged from 25 to 62 percent with an average of 36 percent; drying factor ranged from 1.27 to 1.56 with an average of 1.42; sludge volume reduction efficiencies ranged from 18 to 51 percent with an average of 28 percent; and solids recovery efficiencies ranged from 94 to 99 percent with an average of 98 percent.

In comparing the performance, as shown in Tables 15 and 16, it is evident that a significantly higher sludge solids loading rate and cake solids production rate were obtained with chemical coagulation. The average sludge solids loading rate with chemical usage was 76.2 lb/hr/ft^2 as opposed to 38.9 lb/hr/ft^2 without chemical application. Similarly, the average cake solids production rate with chemical application was 75.2 lb/hr/ft^2 as opposed to that of 38.3 lb/hr/ft^2 without chemical application. Results for the other parameters were about the same.

In comparing the performance of the newly developed vacuum belt dewatering unit with other types of sludge dewatering devices, two parameters appeared worth noting. They were the cake solids production rate and the cost of sludge dewatering. Cake solids production rate of the vacuum belt ranged from 10 to 117 lbs/hr/ft^2, while a cake solids production rate of 1 to 8 lbs/hr/ft^2 was typical for other types of dewatering devices (10,11), such as the vacuum filter or filter press for dewatering municipal waste sludge. However, it should be noted that the cake production rates for the vacuum filter and the filter press used in this comparison were based on dewatering municipal sludge; cake production rates would be different for sludge from a tomato processing plant.

The second significant feature of the vacuum belt dewatering unit was the low cost. For other dewatering devices, such as the vacuum filter, filter press and centrifuges, the unit cost ranges from \$12 to 29/ton dry solids, including capital amortization and operation and maintenance costs (11). The estimated unit cost for the vacuum belt dewatering unit was \$2/ton. This unit cost was estimated based on the following assumptions:

1. Tomato production rate - 120 ton/hr (12)
2. Solids production rate - 15 lbs solid/ton tomato processed (12)
3. Period of operation - 60 days

4. Initial capital cost - $5,000 assuming five years of useable life and straight-line depreciation

5. Man power - 2 man-hour/day at $10/hr

6. Total power of 3 hp (vacuum pump, drive chain and diaphram pump)

In summary, the newly developed vacuum belt dewatering unit appears to be an efficient and cost-effective device for dewatering sludge generated from tomato processing plants.

TOMATO CLEANING RESULTS

TABLE 17 - SUMMARY OF FIRST TEST RESULTS

1. Conventional Washing System

	Fixed Suspended Solids		Mesophilic Aerobic Spores	
Location	ppm	% Red	per ml	% Red
Bin	86	------	2461	------
Dump Tank	59	31	562	77
Inside Wash	38	56	147	94
Final Rinse	6	93	50	98

2. Disc Cleaner with Hollow Cone Nozzle

	Fixed Suspended Solids		Mesophilic Aerobic Spores	
Location	ppm	% Red	per ml	% Red
Bin	82	------	1067	------
Dump Tank	50	39	731	31
Disc Cleaner	27	67	198	81

3. Disc Cleaner with Combination of Nozzles

	Fixed Suspended Solids		Mesophilic Aerobic Spores	
Location	ppm	% Red	per ml	% Red
Bin	116	------	3230	------
Dump Tank	81	30	1178	64
Disc Cleaner	14	88	140	96

Table 18 gives total plate count (TPC) and mesophilic aerobic spores (MAS) results for tomato samples collected from various sample locations. Results are tabulated for the conventional washing system and the disc cleaner operated with the two types of spray arrangements.

These data follow a similar pattern obtained from the first test results. For the disc cleaner, better results were obtained when a combination of sprays were used rather than the hollow cone nozzles. The best results were obtained from tomatoes sampled after the final rinse. The range in percent reduction of spores for the two types of sprays on the cleaner is not as great on a season average as compared to the initial test results. The range for the initial results between hollow cone and combination of sprays was 81% vs. 81%. Disc cleaner results, compared to those from the washer of the conventional system, are much better than those indicated by the preliminary test program. This may be the result of sampling over a longer period of time and reflect the tendency for bacteria to grow in water which has been recirculated for extensive periods of time.

TABLE 18 - SUMMARY OF TOTAL PLATE COUNT (x 10^4) AND MESOPHILIC AEROBIC SPORES, PER GRAM OF TOMATO

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1. Conventional Washing System

	TPC		MAS	
Location	Ave.	% Red	Ave.	% Red
Bin	1841	------	1043	------
Dump Tank	1167	37	971	7
Washer	702	62	612	42
Final Rinse	141	92	86	92

2. Disc Cleaner with Hollow Cone Nozzle

	TPC		MAS	
Location	Ave.	% Red	Ave.	% Red
Bin	1743	------	1862	------
Dump Tank	827	53	1532	18
Disc Cleaner	243	86	432	77

3. Disc Cleaner with Hollow Cone and Flat Jet Nozzle

	TPC		MAS	
Location	Ave.	% Red	Ave.	% Red
Bin	1456	------	1946	------
Dump Tank	1414	3	1040	46
Disc Cleaner	228	84	379	81

Table 19 is a summary of suspended and fixed suspended solids for tomatoes sampled under three cleaning modes. The general pattern for these results is similar to those presented in Table 18 for total plate count and mesophilic aerobic spores. Of the two solids parameters, fixed suspended solids more closely fit the pattern for bacteria data. Spores and fixed suspended solids are normally associated with soil load.

Fixed suspended solids, as previously mentioned, fit the general bacteriological reduction pattern obtained from Table 18. Since suspended solids are highly influenced by the quality of the incoming fruit (soft vs. hard or overripe vs. under ripe), it should more closely correlate with the BOD or COD content of the processing waters.

TABLE 19 - SUMMARY OF TOTAL AND FIXED SUSPENDED SOLIDS, ppm

1. Conventional Washing System

	TSS		FSS	
Location	Ave.	% Red	Ave.	% Red
Bin	189	------	111	
Dump Tank	179	5	86	22
Washer	99	48	30	73
Final Rinse	46	76	8	93

2. Disc Cleaner with Hollow Cone Nozzle

	TSS		FSS	
Location	Ave.	% Red	Ave.	% Red
Bin	213	------	119	------
Dump Tank	153	28	69	42
Disc Cleaner	114	46	30	75

3. Disc Cleaner with Hollow Cone and Flat Jet Nozzle

	TSS		FSS	
Location	Ave.	% Red	Ave.	% Red
Bin	205	------	129	------
Dump Tank	109	47	48	63
Disc Cleaner	84	59	18	86

Table 20 is a summary of water use and the waste generated. Results are expressed as gallons per ton of tomatoes processed or pounds of COD per ton of tomatoes processed.

TABLE 20 - COMPARISON OF WATER AND WASTE GENERATION

1. Final Rinse - Distribution Flume
   Gals/ton = 130
   lbs. COD/ton = 1.0

2. Inside Washer
   Gals/ton = 146
   lbs. COD/ton = 2.44

3. Dump Tank
   Gals/ton = 166
   lbs. COD/ton = 3.42

4. Inside Gutter
   Gals/ton = 216
   lbs. COD/ton = 5.13

5. Disc Cleaner - Hollow Cone Nozzle
   Gals/ton = 3.3
   lbs. COD/ton = 0.1

6. Disc Cleaner - Combination Nozzles
   Gals/ton = 24.7
   lbs. COD/ton = 0.42

Certain estimations and assumptions were made in order to develop some of the data in Table 20. The volume of water used in the final rinse was metered, therefore, the 130 gallons per ton is an accurate figure. To calculate the pounds of COD per ton it was assumed that the 130 gallons per ton of rinse water mixed with the distribution flume recirculation loop and that a sample of the excess water was an indication of the waste generation for the final rinse-distribution flume. Water used inside the plant was 2000 gallons per hour. Some of this water was used to fill the flood washer and some was used for clean up purposes. Since the volume of water for each was not known, it was assumed that 25% of the water was for the flood washer and 75% was used for hosing down. To calculate the pounds of COD it was assumed that the 130 gallons per ton of excess water from the distribution-final rinse and 25% of the 2000 gallons per hour (16 gals/ton) over flowed from the flood washer recirculation system.

The dump tank over flow was derived by adding total excess flow from the inside washer to the bin washing water. Excess over flow was assumed to be 146 gallons per ton and the bin rinse water was assumed to be 20 gallons per ton. The inside gutter, a measure of all water used in the washing and transporting of tomatoes, was the sum of the excess water from the bin dumping and the water used for cleaning.

Table 20 also gives the water use and the waste generated by the disc cleaner when operated under the two types of spray arrangements. Water usage by either mode is significantly lower than conventional washing operations and supports the concept of using mechanical energy as a major substitute for hydraulic energy.

Near the end of the season, it was noted that some of the rubber discs were separating at the fillet junctures. This situation became progressively worse with time and at the conclusion of the test program it was estimated that over 25 percent of the discs had separated at the fillet. This matter was brought to the attention of several concerned parties, with agreement that the problem was caused by having too sharp an angle between the thick and thin part of the disc. It has been recommended that new discs be manufactured which have a greater taper at the fillet juncture.

Some other minor modifications should be made on the disc cleaner as a result of observations made during the study period. The two side walls need to be increased by approximately 4" to prevent occasional tomatoes from bouncing off the disc bed and onto the floor. Permanent spray headers should be installed above the disc bed. There is a need to improve the drive mechanism. The two main drive chains and the two small chains at the front of the cleaner stretched and had to be tightened several times. These matters have been brought to the attention of the manufacturer and solutions have been suggested that should be incorporated into the cleaner before it is operated another season.

Using the disc cleaner, there was no need for the inside washer. As previously indicated, some 1981 gallons of water per hour were used for either filling the washer or hosing down the inside area. Therefore, a potential water savings, from the use of the disc cleaner, would be the total elimination of that water (33 gallons per ton). If the disc cleaner is operated with hollow cone nozzles (3.3 gallons/ton), the water reduction would be approximately 30 gallons/ton or 20% reduction in total water usage.

Another benefit from the use of the disc cleaner, and this aspect has not been fully evaluated, is the potential for a higher quality of water in the distribution flume recirculation system. Limited data on this water system, compared when the two types of cleaning systems were used, indicated the water to be cleaner when the disc cleaner was used. For example, FSS was lower (180 mg/l vs. 229 mg/l) as was SS (391 mg/l vs. 431 mg/l) and COD (847 mg/l vs. 1126 mg/l). When the combination of sprays was used, rather than the hollow cone nozzles, the results were even better, FSS

(180 mg/l vs. 229 mg/l), SS (256 mg/l vs. 431 mg/l) and COD (800 mg/l vs. 1126 mg/l). However, water was increased from 3.3 gallons per ton to 24.7 gallons per ton.

TOMATO CLEANING WITH MAGNUWASHER

In 1976, financial and technical support from Magnuson Engineering, Inc. made possible the demonstration and evaluation of a rubber disc machine of a design significantly different from the flat bed. The machine, called a Magnuwasher (Magnuscrubber), was basically the same equipment developed for dry peel removal of caustic treatment products (known as Model HC Magnuscrubber).

The machine contained parallel rows of soft rubber discs which were arranged in a circle. Built into the center was an auger which provided positive feed of the product. By means of a combination drive mechanism, the rotational speed of the discs on the shafts and the circular rotation could be varied. The circular rotation imparted a tumbling movement to the product and the spinning of the rubber discs provided the cleaning. Water for rinsing was provided by sprays located in the center of the auger.

The sampling and analysis program used in this evaluation was the same as that used for the flat bed disc cleaner. The water flow pattern was also the same.

Two events took place during the 1976 tomato season which adversely impacted the results of the study. The first was a strike by cannery workers, resulting in a delay in harvesting and over ripening of some tomatoes. The second event was unseasonable rains which took place when the tomatomes were being harvested. These events resulted in the delivery to the processing plants of tomatoes of poorer quality than in previous years.

Discussion of Results

The first set of samples was collected September 2, 1976, with daily sampling beginning September 23, 1976.

Table 21 is a summary of the data according to volume of water used by the Magnuwasher. The volume of water used by the Magnuscrubber suggested three groupings for the data. Table 21 shows the individual volumes for each group and gives an average value for each grouping. Grouping was done in this manner to see if varying the volume of water had an effect on cleaning.

TABLE 21

SUMMARY OF MAGNUWASHER EFFLUENT

	Vol.	as mg/L				
Date	gpm	COD	BOD	TSS	FSS	TOC
9-19	3	6710	4605	1870	730	2470
9-2	4	23300	18700	5200	1700	8560
9-14	4	3059	1829	857	147	1011
9-16	4	1490	-	1310	750	530
9-9	5	9233	5333	1500	550	2860
9-22	5	1173	760	373	189	427
AVE	4	7494	6245	1852	678	2643
9-8	6	3945	3393	2197	960	1932
9-18	6	1313	900	535	253	483
9-7	7	7330	4300	1100	100	2410
9-11	8	6100	3167	1000	133	1987
9-13	8	9200	6200	2200	850	3200
AVE	7	5578	3592	1406	459	2002
9-10	10	3567		1033	433	1300
9-15	10	7367	4700	1640	700	2667
9-20	12	3320	1840	1620	900	1210
9-23	14	1045	560	505	198	350
9-21	18	1070	605	1265	335	332
AVE	13	3274	1926	1213	513	1172

TABLE 22

TOMATO RINSE WATER CHARACTERISTICS

	1P (Before Dump)				2P (After Dump Tank)			
Date	TPC	MAS	TSS	FSS	TPC	MAS	TSS	FSS
9-19	>50x10^6	163	144	123	>450x10^6	74	53	24
9-2	65x10^4	700	340	232	30x10^6	70	70	16
9-14	>48x10^6	191	96	59	67x10^6	107	27	9
9-16	25x10^4	120	68	34	16x10^6	48	80	20
9-9	86x10^6	483	107	75	87x10^6	188	26	11
9-22	-	-	37	16	-	-	29	9
Ave.	>37x10^6	331	132	90	>130x10^6	97	43	15
9-8	880x10^6	420	109	72	>103x10^6	232	33	18
9-18	75x10^6	467	95	69	94x10^6	53	34	21
9-7	>10^6	900	300	220	500x10^6	280	26	20
9-11	-	-	79	47	-	-	33	23
9-13	-	-	98	20	-	-	34	11
Ave.	>319x10^6	596	136	86	>232x10^6	377	32	19
9-10	-	156	51	43	-	135	33	21
9-15	10x10^6	326	42	14	33x10^6	243	9	5
9-20	>10^6	260	128	96	>10^6	245	51	39
9-23	-	-	38	8	-	-	42	21
9-21	-	-	55	40	-	-	35	5
Ave.	>5x10^6	247	63	40	>17x10^6	208	34	18

(Continued)

TABLE 22 (CONT'D)

Date	TPC	MAS	TSS	FSS	TPC	MAS	TSS	FSS
9-19	$73x10^6$	27	20	5	$>28x10^6$	42	27	14
9-12	$75x10^4$	40	32	0	$20x10^4$	22	16	0
9-14	$34x10^6$	32	14	0	$167x10^6$	159	11	0
9-16	$>10^6$	18	6	0	$15x10^4$	6	9	5
9-9	$12x10^6$	56	19	0	$41x10^6$	27	19	0
9-22	-	-	23	19	-	-	4	1
Ave.	$>24x10^6$	35	19	4	$>47x10^6$	51	6	3
9-8	$>29x10^6$	28	20	0	$>10^6$	18	17	0
9-18	$19x10^6$	17	15	3	$21x10^6$	18	12	3
9-7	$250x10^6$	80	44	0	$>10^6$	150	88	0
9-11	--	-	27	7	-	-	14	0
9-13	--	-	15	0	-	-	3	0
Ave.	$>99x10^6$	42	24	2	$>7x10^6$	62	27	1
9-10	-	50	7	0	-	34	15	3
9-15	$10x10^6$	25	9	2	$33x10^6$	13	12	0
9-20	$> 10^6$	155	35	8	$>10^6$	20	26	8
9-23	-	-	11	2	-	-	12	8
9-21	-	-	21	2	-	-	3	0
Ave.	$>5x10^6$	77	17	3	$>17x10^6$	22	14	4

It appears that the volume of water has an influence on the characteristics of the effluent. As more water was used, the concentration of measured parameters decreased. The only exception to this is for the FSS at 13 gpm. In spite of the tremendous variability, day to day and even from shift to shift, the averages suggest that valid conclusions can be made. In a later table data for the Magnuwasher will be presented in a different format.

Data are presented in Table 22 for rinse water samples collected from various stages in the processing operation. The designations 1P, 2P, 3P and 4P were previously identified. Results are expressed as mg/l for TSS and FSS; as bacteria per gram of tomato for TPC and MAS. In general TPC results, again highly variable, indicate a cleaning of tomatoes through progressive steps of processing. Of major interest is the comparison of results between 2P and 3P and between 3P and 4P. The results suggest that tomatoes after the Magnuwasher are as clean as those after the final rinse. This point is verified by results of the other tests which are included in Table 21. Visual observations, at the time of processing could not detect any differences between tomatoes examined from 3P and 4P.

Table 23 is a summary of the effluent from the Magnuwasher. Assuming a $22\frac{1}{2}$ hour operating day, the BOD results suggest that varying the volume of water has no effect on the amount of organic matter (tomato material) being discharged. The COD and TOC results were more variable with flow. The TOC increased as the volume of water increased, whereas, COD was maximum at 7 gpm.

For calculations, such as those in Table 23, it would have been most helpful to have known the production rate. Some of the variation in the results were probably due to a change in the quantity of tomatoes being cleaned.

TABLE 23 - CHARACTERISTICS OF EFFLUENT FROM MAGNUSCRUBBER

	lbs. per day		
Flow (gpm)	COD	BOD	TOC
4	337	281	119
7	440	283	158
13	420	282	172

It appears that the Magnuwasher can clean tomatoes with minimal amounts of water required. The spinning rubber discs can remove contaminants from the surface of tomatoes.

In the course of this phase of the study certain things were noted and are offered as constructive suggestions. On several occasions large objects such as wooden material entered the Magnuscrubber causing a shear pin to break, causing a halt in production until a new pin could be inserted. Consideration should be given to the design or to methods of preventing such objects from entering the washer. It is doubtful if sufficient controls can be placed on the harvesting to prevent such objects from being present in the delivered tomatoes. At the discharge end of the Magnuwasher it was noted that trash, vine, leaves, etc. accumulated. This presents an unsightly situation and adds to the time required for cleaning. A redesign of this discharge point could correct this situation.

A question which can not be answered is whether the Magnuscrubber is as gentle in cleaning the product as the flat bed cleaner which was previously evaluated. Because side by side comparisons were not made and because of the poor quality of raw product when evaluating the Magnuscrubber, caution should be exercised regarding this matter.

SECTION 6

ECONOMIC ANALYSIS

An economic evaluation has been made and is presented in the following on the cost-effectiveness of the alternative water recycle and cleaning methods considered for a tomato processing industry discharging to a municipal waste-water collection and treatment system. The total costs of a system for tomato fluming and cleaning include the following:

1. Cost of water
2. Wastewater treatment costs
3. Energy costs
4. Equipment capital cost and depreciation cost
5. Solid waste disposal cost
6. Chemical cost
7. Labor and maintenance cost
8. Indirect costs

The cost-effectiveness evaluation performed is based on parameters derived during the study. The parameters required for the analysis of alternative systems are itemized on Table 24 for four alternative water recycle and cleaning systems considered. Additionally, the following assumptions were utilized in the cost-effectiveness evaluation:

1. The cost of water at $0.20 per 100 cubic feet.
2. The cost of energy at $0.04 per kwhr.
3. The systems were operated at the average capacity noted during the study.

4. The period of operation was 60 days.

5. The total unit solid loading rate was equal to 15 lbs/ton of tomatoes processed.

6. Unit solids loadings (based on average solids distribution as indicated on Table 12.

7. The equipment capital cost was financed over 10 years at 10 percent interest.

8. Solid hauling cost was $3.00 per cubic yard.

9. Labor, maintenance, and indirect costs remain the same for all alternative systems.

10. The chemical clocculant cost was equal to $0.65/lb.

Because of the significance of wastewater treatment costs and their wide variation, the analysis of the wastewater treatment cost for the alternative systems have been compared with three wastewater agencies. A comparison of industrial wastewater charges for San Jose, East Bay Municipal Unitility District (EBMUD), and Sacramento are presented on Table 25. Wastewater treatment charges for industry are generally based on a combination of the capacity of the treatment plant made available plus the cost of treating the waste. Costs for waste treatment are made up of charges for flow and pollutant loadings such as BOD or COD, and suspended solids. For a seasonal industry, the cost of the treatment plant capacity made available to that industry can become very important. It must be noted that the comparison of wastewater charges does not include monitoring costs, separate collection system costs, or any ad valorem taxation that pays for a portion of the treatment costs. Inclusion of ad valorem taxes can have a widely varying impact depending upon the tax rate allocable to waste treatment services and the assessed valuation of the facilities utilized.

Wastewater treatment charges listed on Table 25 were applied to the four alternative recycle and cleaning systems against charges for San Jose, EBMUD, and Sacramento. A summary of these results, reported as a unit cost per ton of product, is presented on Table 26. The significance of demand charges on a seasonal industry is demonstrated in this table. For the 60-day operation considered in this analysis, the demand charges approximate the loading charges. Table 26 also demonstrates the significance of high COD or BOD and suspended solids loading to the sewers. For the cases considered, COD or BOD and suspended solids loading represented significantly higher costs for all alternative systems than did costs for treating the volume of flow. This suggests that reduction in organic loading

TABLE 24

PARAMETERS FOR ANALYSIS OF ALTERNATIVE SYSTEMS

Parameter	Conventional with Recycle	Modified Conventional with Recycle and Solids Concentration	Disc Cleaning with Recycle and Solids Concentration	Disc Cleaning with Recycle Solids Concentration and Flocculation
Tomatoes processed (tons/day)	481	445	594	605
Peak Tomatoes processed (ton/day)	520	560	675	634
Avg. Water Use (gal/ton)	278	245	156	164
Avg. Wastewater flow (gal/day)	134,000	109,000	93,000	99,000
Peak Daily Wastewater flow (gal/day)	152,000	124,000	107,000	111,000
Avg. Suspended Solids mg/l	8,000	3,000	1,000	800
Avg. COD mg/l	2,750	1,583	4,575	4,430
Avg. BOD_5 mg/l	1,100	662	2,521	1,767
On-Site Solid Waste (lbs/ton)	5.9	9.5	13.1	13.8
Energy Usage (kwhr/ton)	0.411	0.947	0.841	0.867
Equipment Cost ($)	33,000	99,300	92,900	105,800

TABLE 25

COMPARISON OF INDUSTRIAL WASTEWATER CHARGES

Charge	San Jose[a]	EBMUD[b]	Sacramento[c]
Demand			
Flow, mgd/yr ($)	20,500	- - -	10,344
BOD, 1000 lb/day/yr ($)	1,690	- - -	3,840
SS, 1000 lb/day/yr ($)	990	- - -	960
NH_3, 1000 lb/day/yr ($)	24,930	- - -	- - -
Loading			
Volume, $/mg	119	116[d]	68.80
BOD, $/1000 lb	20	- - -	34.70
COD, $/1000 lb	- - -	61	- - -
SS, $/1000 lb	26	44	34.50
Ad valorem taxes ($/100 A. V.)	- - -	$0.07	$0.242

[a] Rates adopted for 1976/77

[b] Proposed rates for 1977/78 (includes Industrial Cost Recovery in rates)

[c] Proposed rates for 1977/78

[d] 7.3¢/100 of water used

TABLE 26

SUMMARY OF WASTEWATER TREATMENT COSTS

Charge	Conventional with Recycle			Conventional w. Recycle and Solids Concentration			Disc Cleaner w. Recycle and Solids Concentration			Disc Cleaner w. Recycle Floc. and Solids Conc.		
	San Jose	EBMUD	Sacto	San Jose	EBMUD	Sacto	San Jose	EBMUD	Sacto	San Jose	EBMUD	Sacto
Demand												
Flow $	3,116	--	1,572	2,542	--	1,283	2,193	--	1,107	2,276	--	1,148
BOD $	2,357	--	5,355	1,157	--	2,629	3,801	--	8,639	2,764	--	6,281
SS $	10,040	--	9,736	3,071	--	2,978	833	--	856	733	--	711
TOTAL	15,513	--	16,663	6,770	--	6,839	6,877	--	10,602	5,773	--	8,140
Cost/ton over Season	0.538	--	0.577	0.254	--	0.256	0.193	--	0.297	0.159	--	0.224
Loading												
Volume $/ton	0.033	0.032	0.019	0.029	0.028	0.017	0.019	0.018	0.011	0.020	0.019	0.011
COD $/ton	--	0.389	--	--	0.197	--	--	0.363	--	--	0.370	--
BOD $/ton	0.051	--	0.088	0.027	--	0.047	0.066	--	0.114	0.048	--	0.084
SS $/ton	0.482	0.816	0.640	0.159	0.270	0.211	0.034	0.057	0.045	0.028	0.048	0.038
TOTAL	0.566	1.237	0.747	0.215	0.495	0.275	0.119	0.438	0.170	0.096	0.437	0.113
TOTAL Cost $/ton	1.104	1.237	1.324	0.469	0.495	0.531	0.312	0.438	0.467	0.255	0.437	0.357
TOTAL Treatment Cost[a] $	31,860	35,700	38,210	12,522	13,216	14,177	11,120	15,610	16,640	8,256	15,863	12,959

[a] $/ton times tons processed over 60-day season.

and suspended solids could significantly reduce wastewater treatment costs. Reduction in the flow and suspended solids discharge to the municipal sewer results in significant reductions in overall wastewater treatment charges. The conventional system with recycle and no solids concentration had the highest wastewater treatment charges as a result of high water use and high suspended solids discharge. The disc cleaning system with solids concentration and flocculation had the lowest wastewater treatment charges as a result of minimum water and suspended solids discharge to the sewers. The significance of water conservation and in plant pretreatment of wastes is clearly demonstrated by savings in wastewater treatment costs.

A summary comparison of the wastewater treatment costs for alternative recycle systems is presented on Table 27. By minimizing water use with disc cleaning and subsequent flocculation and solids concentration, the costs of wastewater treatment can be reduced to 25 to 30 percent of the cost of a conventional countercurrent recycle system with no solids concentration. In-house treatment methods and the utilization of disc cleaner which minimized water consumption would result in lower wastewater treatment costs. For the City of Sacramento, the resulting savings would be equivalen to approximately \$1.00/ton of tomatoes processed. The use of the modified conventional washing system plus recycle and solids concentration would result in a savings of approximately 60 percent over the system with no solids concentration.

A summary of the total costs for tomato cleaning for the alternative recycle systems considered is presented on Table 28. This table summarizes all identifiable costs for the alternative systems where the costs were not equivalent for all systems considered. The costs range from a high of approximately \$1.50/ton for the modified conventional washing system with recycle to a low of \$0.92/ton for the disc cleaning system with water recycle and solids concentration. The advantages of utilizing water recycle systems and water conservation systems for overall cost savings is clearly demonstrated by this table. In this analysis the overall costs, including capital costs of the required equipment is reduced as much as \$0.59/ton of tomatoes processed, hence a potential net annual savings of approximately \$20,000/year for a 36,000 ton/year season. These savings represent a substantial return on the investment as these are direct savings in operating costs.

The cost of wastewater treatment and equipment capital cost are by far the dominant costs for each alternative considered. Disc cleaning and water recycle with solids concentration resulted in higher energy consumption, equipment costs, and in-house solid waste disposal costs than the conventional system. The use of chemical flocculation resulted in an additional cost for chemicals that was not present in the other alternative systems. However, lower costs for water and wastewater treatment resulted in lower overall costs for disc cleaning and water recycling with solids concentration.

The 25% increase in the processing of tomatoes with the water recycle systems has economic savings other than those associated with waste treatment costs that have been discussed. Compared to the conventional method of processing, the 25% increase can be translated into the potential of processing an additional 140,000 tons of tomatoes without additional costs. That is 30 tons/hr x 20 hrs/day x 60 days/season = 720,000 tons vs. 37.5/ton/hr x 20 hrs/day x 60 days/season = 860,000 tons.

Another way of interpreting the potential savings from using the water recycle system is to compare processing time for a given tonnage of tomatoes. For example, 60 days of conventional processing is required for a through put of 720,000 tons. With recycle the same tonnage can be processed in 45 days, a labor savings of $54,000 per season.

TABLE 27

SUMMARY COMPARISON OF WASTEWATER TREATMENT COSTS FOR ALTERNATIVE RECYCLE SYSTEMS

Recycle System / Agency	Modified Conventional Washing plus Recycle $/ton	Modified Conventional Washing plus Recycle and Solids Concentration $/ton	Disc Cleaning plus Recycle and Concentration $/ton	Disc Cleaning plus Recycle, Flocculation and Concentration $/ton
San Jose	1.104	0.469	0.312	0.255
EBMUD	1.237	0.495	0.438	0.437
Sacramento	1.324	0.531	0.467	0.357
Average	1.222	0.498	0.406	0.350

TABLE 28

SUMMARY OF COSTS FOR TOMATO CLEANING

Overall Cost $/ton	Modified Conventional Washing with Recycle	Modified Conventional Washing with Recycle and Solids Concentration	Disc Cleaning with Water Recyle and Solids Concentration	Disc Cleaning with Water Recycle, Solids Concentration and Flocculation
Water Use	0.074	0.066	0.042	0.044
Wastewater Treatment	1.222	0.498	0.406	0.350
Energy	0.016	0.038	0.034	0.035
Equipment Capital Cost	0.186	0.605	0.424	0.474
Solid Waste Disposal	0.005	0.009	0.012	0.013
Flocculant	- - -	- - -	- - -	0.017
TOTAL	1.503	1.216	0.918	0.933

Potential net annual savings = (1.503 - 0.933) (36,000 ton/year) = $20,520

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